THE BIOLOGY OF HERRING FROM BRAS D'OR LAKE
CAPE BRETON, NOVA SCOTIA

by

R.H. Crawford, D.M. Webber and G. Boutlier

Manuscript and Technical Report Series

Project Report No. 82-04

Nova Scotia
Department of Fisheries

THE BIOLOGY OF HERRING FROM BRAS D'OR LAKE CAPE BRETON, NOVA SCOTIA

by

R.H. Crawford, D.M. Webber and G. Boutlier

Nova Scotia Department of Fisheries
Marine Resources Division
1982

TABLE OF CONTENTS

	Page
List of Figures	i
List of Tables	iii
Introduction	1
Materials and Methods	2
Commercial Fishery Sampling	2
Meristic Characters	4
Fecundity	5
Egg and Larval Survey	6
Results	9
General Sampling Data (Commercial Fishery)	9
Length and Age Composition	9
Growth Relationships	12
Length - Weight	15
Feeding Intensity	18
Gonad Maturity	22
Nematode Incidence	25
Meristics	27
Fecundity	30
Egg and Larval Survey, Ross Cove	34
Spawning	34
Spawning Bed Characteristics	34
Physical	34
Egg Deposition	36
Egg Mortality	38

TABLE OF CONTENTS continued

Page

Larval Density and Dispersal ---------- 38

Larval Growth ---------- 41

General Observations on Spawning in North Cove, 1980---------- 44

Discussion ---------- 45

Adult Biology ---------- 45

Early Life History ---------- 50

Stock Analysis ---------- 58

Acknowledgements ---------- 60

References ---------- 61

LIST OF FIGURES

		Page
Fig. 1	West Bay, Bras d'Or Lake, Cape Breton, Nova Scotia	3
Fig. 2	Map of North Cove and Ross Cove of West Bay, Bras d'Or Lake showing the spawning beds and sampling locations	7
Fig. 3	Length and age composition of herring samples from West Bay, Bras d'Or Lake for 1980 and 1981	10
Fig. 4	Mean total length-at-age for herring sampled from West Bay, Bras d'Or Lake compared with mean lengths for herring sampled along the Atlantic coast and Northumberland Strait	14
Fig. 5	Length-weight relationship for herring samples from West Bay, Bras d'Or Lake compared to herring samples from the south shore (Lunenburg and Queens Counties), north shore (Caribou-Pictou) and Chedabucto Bay (Isle Madame)	16
Fig. 6	Length-somatic weight relationship for male herring samples from West Bay, Bras d'Or Lake for 1980 and 1981	19
Fig. 7	Length-somatic weight relationship for female herring samples from West Bay, Bras d'Or Lake for 1980 and 1981	20
Fig. 8	Degree of stomach fullness in fish sampled from West Bay, Bras d'Or Lake for 1980 and 1981	21
Fig. 9	Gonad maturation of herring sampled from West Bay, Bras d'Or Lake in 1980 and 1981	24
Fig. 10	Percentage nematode incidence relative to fish length for herring from West Bay, Bras d'Or Lake (1980, 1981) compared to incidence levels in herring from the Atlantic coast and Northumberland Strait	26

LIST OF FIGURES (continued)

Page

Fig. 11 Mean number of dorsal, anal, and pectoral fin rays and gill rakers for spring spawning fish from Bras d'Or Lake and autumn spawning fish from East Chezzetcook for the year 1980---------- 28

Fig. 12 Scatter diagram and fitted regression curve of fecundity and length relation of Bras d'Or Lake, West Bay herring samples---------- 31

Fig. 13A Density of herring eggs on algae at the spawning site in Ross Cove during the incubation and hatching periods---------- 37

Fig. 13B Percentage occurrence of unhatched, hatched and dead eggs during the incubation and hatching phases---------- 37

Fig. 14A Estimates of herring larval density during the hatching period in Ross Cove---------- 39

Fig. 14B Mean length of larvae samples in Ross Cove during the hatch and post hatch periods---------- 39

LIST OF TABLES

		Page
Table I	Mean total length and age of herring from West Bay, Bras d'Or Lake relative to different gill net mesh sizes (1980-81)---------	11
Table II	Mean total length, weight and condition factor-at-age for herring samples from West Bay, Bras d'Or Lake for the years 1980, 1981----------	13
Table III	Stages in maturity and the description of the gonads of herring in the various stages according to ICNAF (1964)----------	23
Table IV	Test for significance of differences of the mean number of dorsal fin rays, pectoral fin rays, anal fin rays and gill rakers between East Chezzetcook and Bras d'Or Lake samples for the year 1980----------	29
Table V	Relations between log fecundity and log length and between log fecundity and log weight of spring spawning herring from the Bras d'Or Lake, West Bay area----------	32
Table VI	Mean fecundity estimates ('000) and predicted values by length group of spring spawning Bras d'Or Lake (West Bay) herring and predicted values for spring spawning herring of the Canadian Maritimes area reported by various authors----------	33
Table VII	Physical and biological characteristics of the spawning bed at Ross Cove, West Bay, Bras d'Or Lake 1981----------	35
Table VIII	Larval density at Ross Cove stations (RC_1-RC_5) based on vertical net hauls during the hatching period----------	40

LIST OF TABLES (continued)

		Page
Table IX	Exploratory plankton net tows in West Bay for herring larvae-------	42
Table X	Length frequency of larvae relative to days from spawning and sampling location----------	43

Introduction

The Bras d'Or Lake system is essentially a large (1,100 km^2), brackish water estuary. The freshwater input is relatively small and in the open areas of the system the surface salinity is approximately $20^{o}/oo$ (2/3 seawater), with a maximum of $25\text{-}26^{o}/oo$ at depth (Krauel, 1975). However, there is considerable variation in surface salinity of the coves, dependent on season, freshwater input, meteorological conditions and land configuration (pers. obs.). Since water can only enter the Bras d'Or Lake system via Great Bras d'Or and Little Bras d'Or channels the tidal effect is greatly weakened, being approximately 0.25 m at Baddeck and 0.15 m or less in Bras d'Or Lake. The wind and other meteorological conditions appear to be more important as factors determining currents and water level, except in the narrow channels, e.g. Little Narrows (Krauel, 1975).

The main commercial fishery in the Bras d'Or Lakes is for herring (Clupea harengus L.). In April and early May, shortly after the ice disappears, herring move into shallow waters to spawn. During this time they are intensively fished by gill net operations. The fishery has become increasingly more important as a source for lobster bait and human consumption. Though accurate yearly landings are not available the catch appeared to peak in 1980 and then declined markedly in 1981.

From the biological viewpoint little is known of the Bras d'Or Lake herring population. Consequently, a study was undertaken for the purpose of assessing some of the adult population characteristics of size and age composition, growth, gonad maturity, feeding, meristics and fecundity. A tagging program has also been initiated to establish the extent of migration and the possible affiliation of this stock with other stocks outside the Bras d'Or Lakes. Since the early life history of fish appears to be extremely important in understanding population dynamics, egg and larval surveys were implemented to study: (1) spawning substrate, environmental conditions, egg density and mortality; and (2) larval production, dispersal and growth.

Materials and Methods

Commercial Fishery Sampling

Herring samples were obtained from commercial fishermen located in West Bay, Bras d'Or Lake in 1980 and 1981 (Fig. 1). Most samples were initially frozen and then thawed for examination at a later date. Some samples were examined in the fresh stage. Routine examination of each specimen involved the recording of total length, whole weight gonad weight, number of nematodes, degree of stomach fullness, stage of maturity and the removal of otoliths for later age determination. Length measurement in mm was from the tip

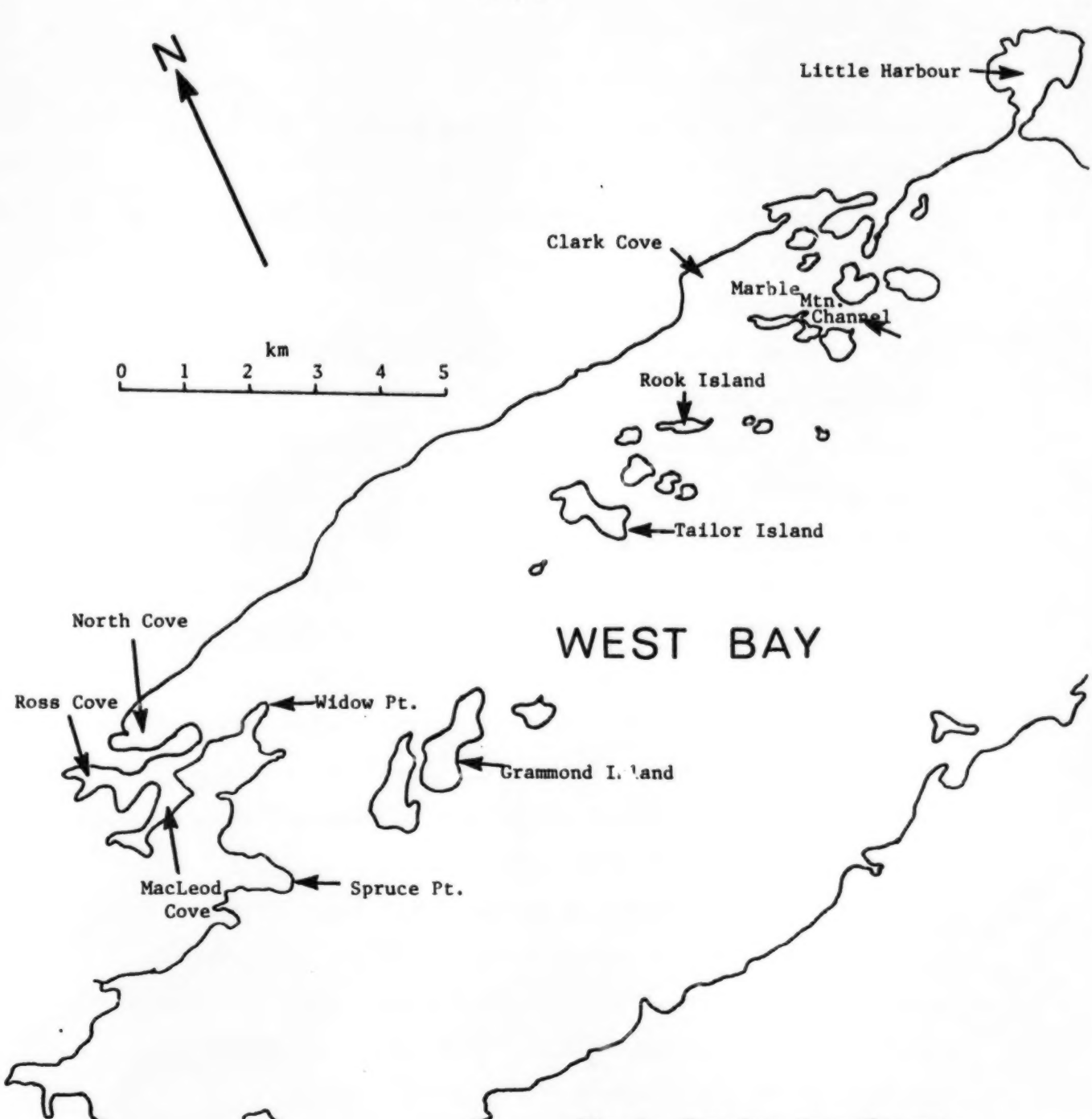

Fig. 1. West Bay, Bras d'Or Lake, Cape Breton, Nova Scotia.

of the lower jaw to the end of the caudal fin. Whole weight was determined to the nearest g and gonad weight to the nearest 0.1 g.

The stage of gonad maturity was determined by gross examination of the gonads using the method of staging, adopted by ICNAF, 1964.

Examination for larval nematodes centered on the body cavity and internal organs with associated mesenteries. Parsons and Hodder (1971) found less than 1% of the specimens had nematodes in the musculature so that this body component was excluded from examination.

Stomach fullness was estimated according to the following categories: o = empty; 1 = 0-25% full; 2 = 25-50% full; 3 = 50-75% full; 4 = 75-100% full.

Age determinations were made by examination of the whole otolith using a binocular dissecting microscope. The aging procedure was based on the method used by the Biological Stations (Fisheries and Oceans) at St. Andrews, N.B. and St. John's, Nfld. (Hunt and Winters, MS, 1979). The samples consisted entirely of spring spawners so the age group was recorded as the number of completed winter zones (hyaline). Three readers aged the otoliths independently and age recorded through mutual agreement or by majority decision.

Meristic Characters

Counts of meristic characters were made on all of the Bras d'Or Lake samples collected in 1980. For comparison purposes counts were also made on 168 autumn spawning herring collected from East Chezzetcook, Halifax Co., from May - July,

1980.

Anal, dorsal and left pectoral fin rays were counted, including rudimentary rays. Of the median fins, the last split ray originating from the same base was counted as one. The left first gill arch was removed and preserved in 10% formalin for later examination. The gill rakers of the lower branch (hypobronchial and ceratobranchial) were counted including all rudimentary rakers. The bifurcated raker at the bend of the arch was counted as one.

Fecundity

Pairs of ovaries were collected from 45 fish from the 1980-81 herring samples. The 1980 fecundity samples were collected just prior to or at the stage of spawning (stage 6). The 1981 samples were collected in advance of spawning (stage 4-5). Care was taken to select fish that did not appear to have shed eggs.

Ovaries were preserved in jars containing Gilson's fluid for a minimum of 4 weeks. The jars were periodically shaken to facilitate separation of the eggs. The eggs and fluid were poured into a large container, the fluid was decanted and the process repeated using water until the liquid was clear. The eggs and liquid were then poured into a funnel, containing a fine mesh filter, and connected to an aspirator. The eggs were filter dried for 40 min. at a constant aspirator vacuum. Eggs were then transferred to weighing containers and weighed to the nearest 0.01 g (Mettler, Model PC 4400).

Fecundity was then estimated by taking 3 subsamples and carefully weighing each to the nearest 0.01 g. The subsamples ranged in weight from 1.00 to 1.69 g. The eggs in the subsample were counted in groups of 100 using a binocular microscope. Numbers of eggs in each subsample ranged from 1,185 to 4,084. To test if fecundity estimates varied with the weight of the subsample a range of weights were utilized (0.74 g - 1.36 g - 2.36 g). Fecundity did not vary significantly with subsample weight and maximum variation was only 0.63%.

Fecundity (absolute) was expressed as the number of eggs per female. Fecundity, total length and weight were transformed into natural logarithms and the parameters determined using linear regression analysis.

Egg and Larval Study

A herring spawning bed was examined during April and May, 1981, within Rose Cove, West Bay, Bras d'Or Lake (Fig. 2). A marker buoy (RC_1) was positioned on the spawning bed in an area of high egg density. Four other buoys (RC_2-RC_5) were positioned at progressively further intervals from the spawning site to determine the magnitude of larval dispersal. Sampling at the spawning bed (RC_1) included the determination of surface water temperature and bottom salinity by means of a Hach conductivity meter. Samples of bottom vegetation with attached herring eggs were taken and preserved in 5% formalin.

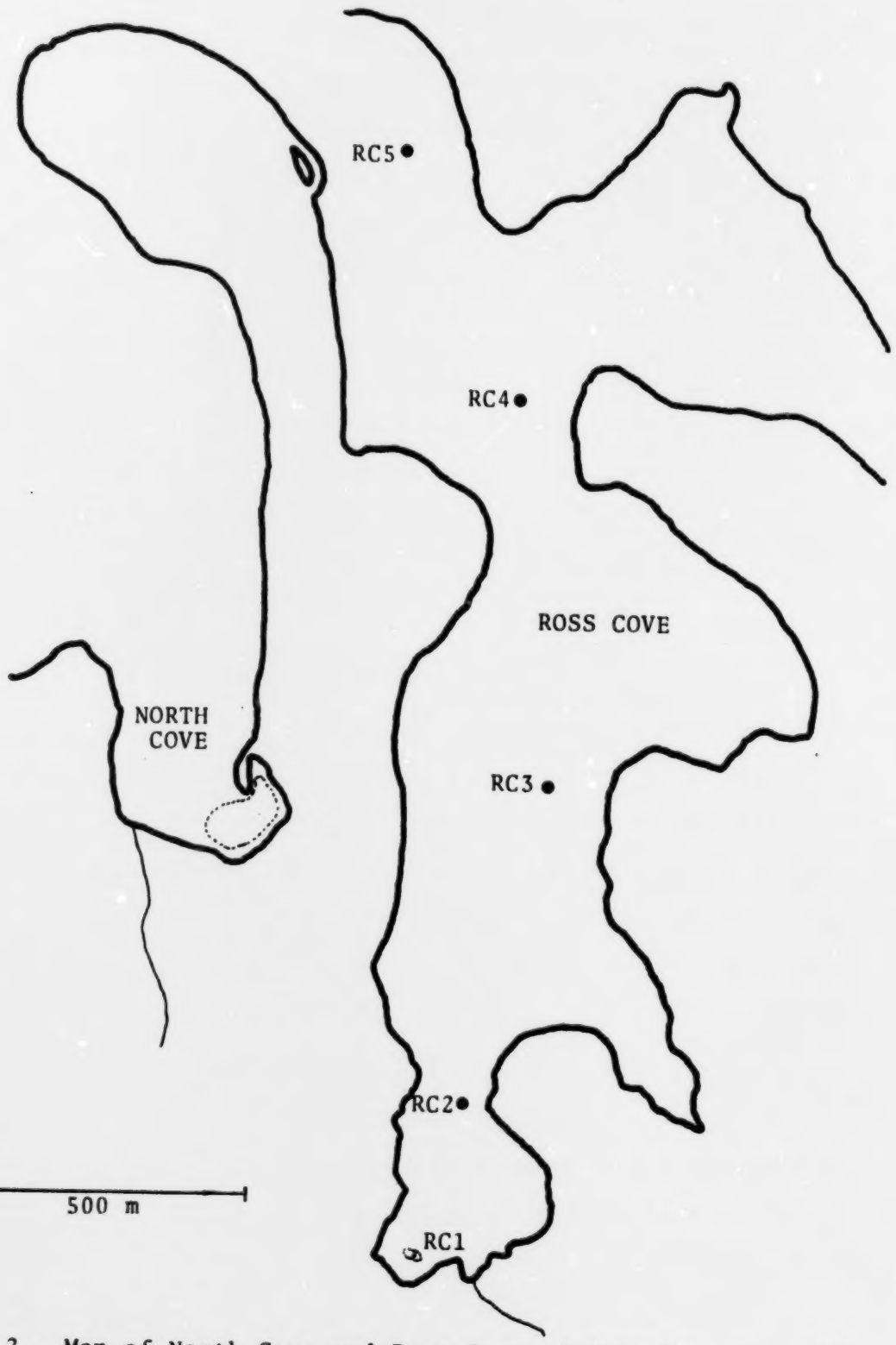

Fig. 2. Map of North Cove and Ross Cove of West Bay, Bras d'Or Lake showing the spawning beds (dotted area) and sampling locations (RC1-RC5).

To determine the concentration of eggs the sample was emptied into a tray and strands of eelgrass were randomly drawn from the sample. Eggs were stripped from the seaweed and counted using a Wild dissecting microscope. The subsample of seaweed was then weighed to the nearest 0.01 g and the concentration calculated as the number of eggs per g seaweed. Egg mortality was determined by counting the number of opaque, white eggs and expressed as a percentage of the total number of eggs in the subsample. Hatching was assumed to have occurred when only the egg capsule remained and was expressed as a percentage of the total number of eggs (unhatched, dead, hatched).

Larval concentration over the spawning bed was determined using a 0.5 m diameter plankton net with mesh size .350 mm. The net was lowered to the bottom and hauled up vertically to the surface. The volume of water sieved was calculated by the formula $\pi r^2 h$ and the concentration of larvae as the number per m^3. A small sieve was also utilized at RC_1 to determine larval numbers. The sieve consisted of a plexiglass cylinder (diam. -20cm; depth -30cm) with a .350 mesh screen across the middle of the cylinder the sieve was lowered horizontally into the water to a depth of 30 cm and then hauled vertically to the surface. The same procedure was repeated 10 times and the concentration expressed as the mean number per sieve haul.

Vertical plankton hauls were also implemented at stations RC_2 - RC_5 during the period of hatching and the concentration of larvae per m^3 determined. Surface water

temperatures, wind direction and velocity were also recorded at the time of net hauls.

Horizontal and vertical tows were conducted at other locations in West Bay. In the horizontal tows the plankton net was towed near the surface at a constant boat speed for a designated period of time. The vertical hauls consisted of lowering the net to the bottom and vertically hauling it to the surface.

In order to assess larval growth samples of larvae were measured for total length using an eyepiece micrometer in the dissecting microscope. Samples for length measurement were taken from the daily net hauls conducted during the hatching period at RC_1 (Apr. 27th to May 2nd) and at RC_5 (May 5th).

Results

General Sampling Data (Commercial Fishery)

The spring herring fishery in the Bras d'Or Lake starts after the ice break-up and extends for a 3-4 week period. In 1980 the sampling period extended from April 21 to May 1st. With an earlier spring in 1981 the sampling period was from April 1 to May 5th. A total of 297 fish were sampled in 1980 and 179 in 1981. The male/female ratio was 1.04 in 1980 and 0.60 in 1981.

Length and Age Composition

The length-frequency composition of the 1980-81 samples are shown in Fig. 3. For 1980 the length range was

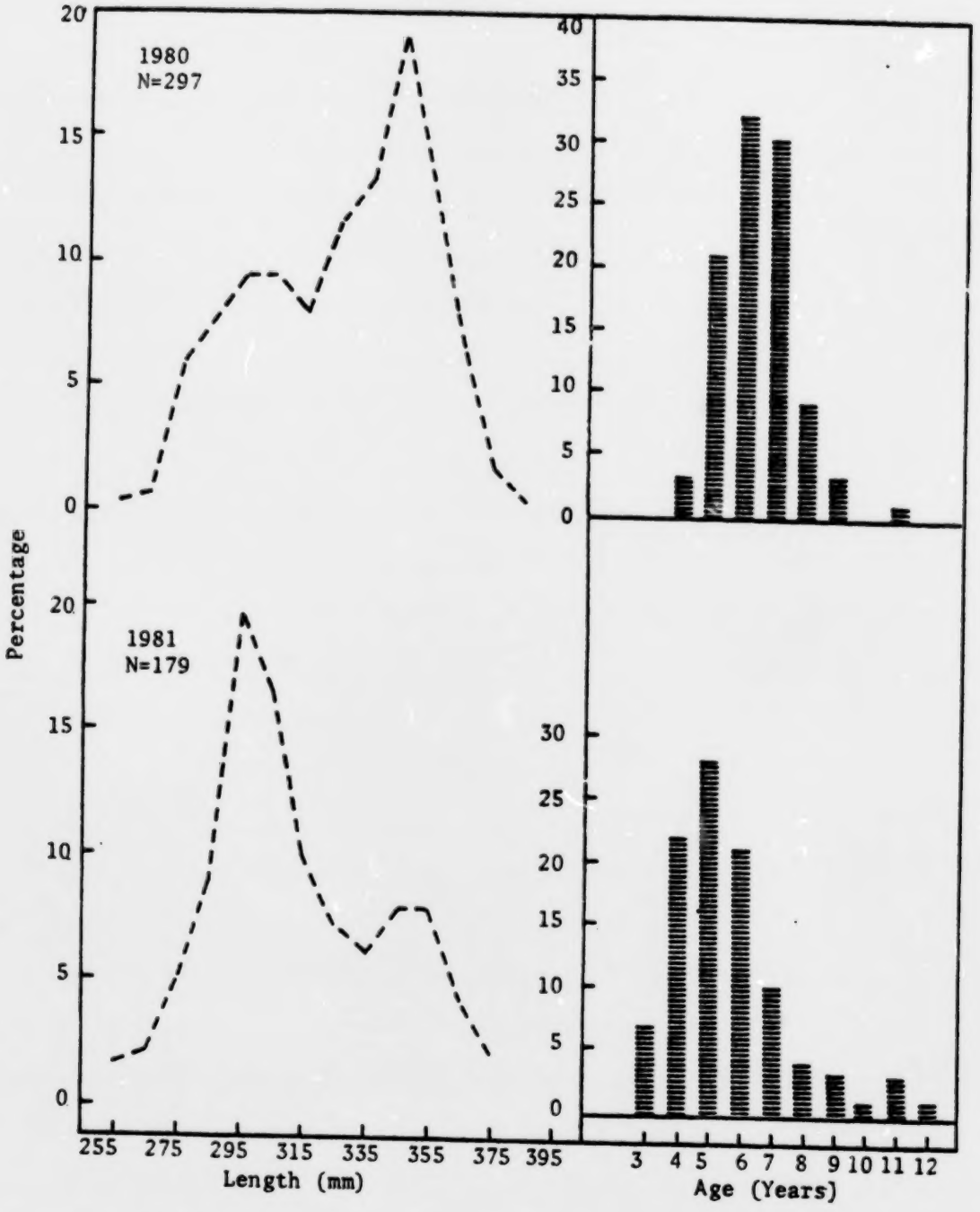

Fig. 3 : Length and age composition of herring samples from West Bay, Bras d'Or Lake for 1980 and 1981.

260-380 mm, with a mode of 345 mm and mean of 328 mm. The 1981 sample included a greater percentage of smaller fish with a range of 250 - 380 mm, mode of 295 mm and mean length of 313 mm. Both years show a certain degree of bimodality which is not a reflection of population length frequency but of sample selection from specific gill net mesh sizes. In 1980 the samples came primarily from a mesh size of 73 mm (2 7/8"), whereas in 1981 a greater proportion of the sampling was from smaller mesh sizes, 57-67 mm (2 1/4 - 2 5/8").

The age composition of the samples also reflects the selectivity factor of gill nets. For 1980 the 6 year-old fish (1974 year class) formed the highest percentage but also with a high proportion of 7 year-old fish. In 1981, the 5 year-old fish (1975 year class) predominated but also with significant numbers of 4 and 6 year-old fish.

Since gill net selection is an important aspect of the commercial catch sampling a more detailed analysis of length and age composition of selected mesh sizes is shown in Table I, based on data from the 1980-1981 sampling.

Table I. Mean total length and age of herring from West Bay, Bras d'Or Lake relative to different gill net mesh sizes (1980-81).

Mesh size mm (inches)	Mean Length mm (in.) ± 1S. D.	Mean Age yr. ± 1S. D.
57 (2 1/4)	293 (11.5) ± 10	4.5 ± 0.5
67 (2 5/8)	311 (12.2) ± 21	6 ± 1.1
73 (2 7/8)	333 (13.1) ± 23	6.5 ± 1.1

Growth Relationships

The growth parameters of length, weight and condition factor-at-age are shown in Table II for the years 1980 and 1981. Length-at-age data for the two years are similar and shown in Fig. 4, along with data for herring sampled along the Atlantic Coast and eastern Northumberland Strait (Crawford, 1980). At age 3 the mean length of herring from the Bras d'Or Lake was 274 mm compared to a mean length of 243 mm for herring sampled along the eastern shore (Halifax County) in 1979. The length-at-age 3 data from the south shore (Lunenburg and Queens Counties) was also less than Bras d'Or Lake herring. However, for fish aged 4-11, the mean length-at-age values were generally less than for fish sampled along the Atlantic Coast and eastern Northumberland Strait, though overlap occurs at age 7 and 8.

The mean weight-at-age values for herring from the Bras d'Or Lake were generally less than for fish sampled along the Atlantic Coast and Northumberland Strait in 1979, with the exception of age 3. This is primarily a result of the maturation stage of the fish, with prespawning, spawning and partially spent fish. The statistical variation in weight-at-age was considerably greater than for length-at-age. In 1980 the coefficient of variation for weight-at-ages 4-9 ranged from 14-38% whereas the coefficient of variation for length ranged from 4-9%. In 1981 the coefficient of variation for weight-at-ages 3-9 ranged from 5-17% and for length, 1-4%.

Condition factors were determined for each age group, based on the formula weight/length^3. For the 1980 sample and

Table II: Mean total length, weight and condition factor-at-age for herring samples from West Bay, Bras d'Or Lake for the years 1980, 1981.

Year	Age	Mean Length mm ± 1 S.D.(N)	Mean Weight g ± 1 S.D.	Mean Condition * Factor ± 1 S.D.
1980	4	284±25(9)	187±71	0.78±0.08
	5	308±21(56)	238±67	0.80±0.08
	6	323±22(85)	282±81	0.81±0.11
	7	340±19(80)	337±65	0.85±0.08
	8	342±17(23)	329±47	0.82±0.09
	9	352±13(9)	384±67	0.88±0.12
1981	3	274±10(11)	165±24	0.80±0.06
	4	286±10(35)	182±23	0.78±0.04
	5	302±8(44)	207±28	0.75±0.08
	6	318±11(33)	265±45	0.82±0.08
	7	340±7(15)	337±41	0.86±0.10
	8	349±6(6)	360±49	0.85±0.08
	9	353±4(5)	426±23	0.97±0.06
	11	361±3(4)	402±22	0.86±0.05

*Condition factor = $\frac{\text{weight}}{\text{length}^3}$

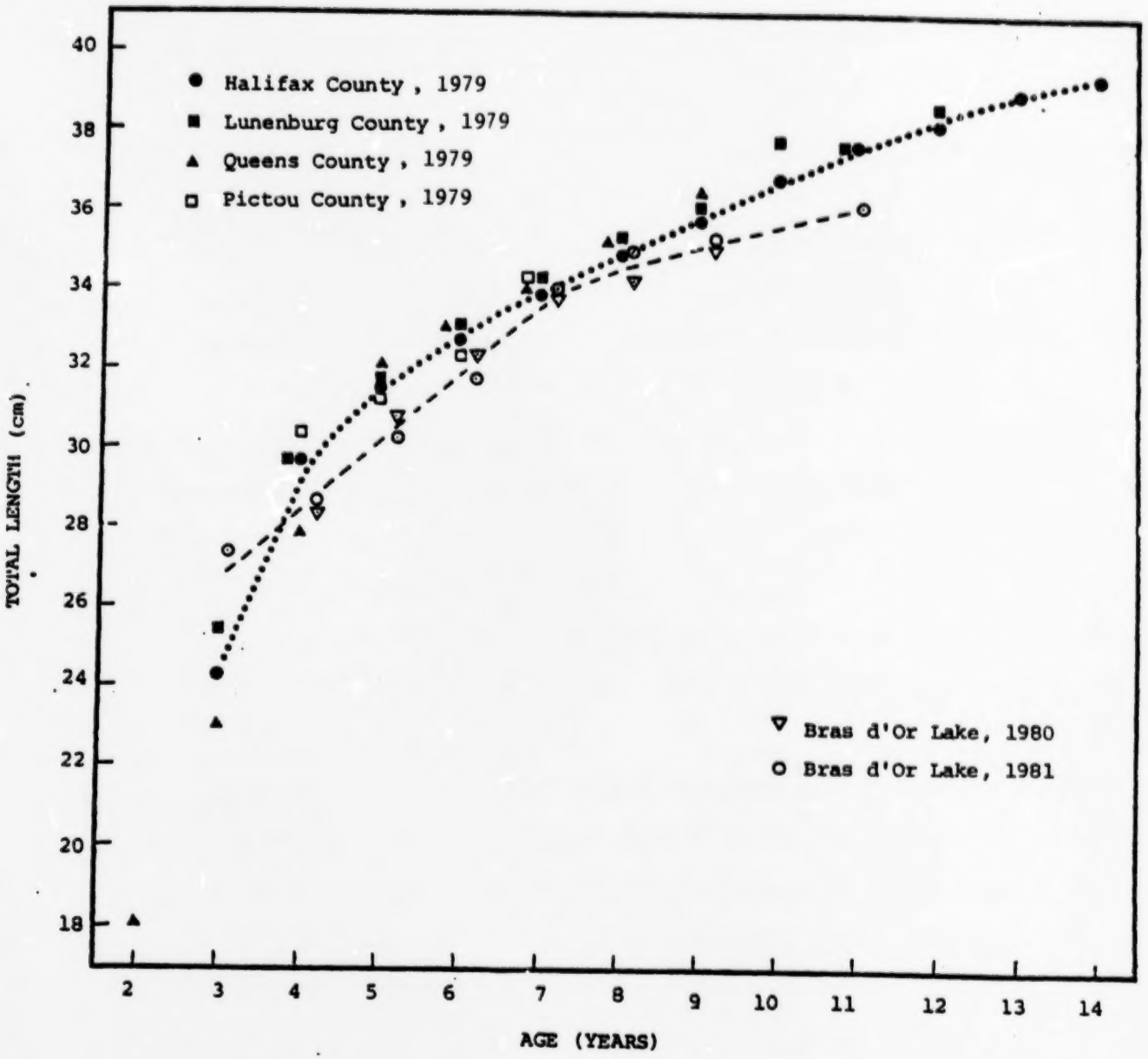

Fig. 4 Mean total length-at-age for herring sampled from West Bay, Bras d'Or Lake compared with mean lengths for herring sampled along the Atlantic coast and Northumberland Strait (Crawford 1980). The dotted line represents a fit of the combined data for Halifax, Lunenburg and Queens Counties (1979). The broken line is a fit of the Bras d'Or Lake data for the years 1980, 1981.

ages 4-9 the condition factor ranged from 0.78 to 0.88 with a mean of 0.82. The condition factor for the 1981 sample for ages 3-11 ranged from 0.75 to 0.97, with a mean of 0.81. These values reflect the spawning condition of the stock since the mean condition factor of primarily prespawning fish from Caribou-Pictou Island was 0.92 in 1979 (Crawford, 1980) and 0.94 in 1980.

In fish sampled along the eastern shore in 1979, the mean condition factor increased from 0.83 in May to 0.95 in August, due primarily to the maturation of the gonad. Similar results have been recorded for samples from the east and south shore in 1980. Herring samples were also taken from Isle Madame in May, 1980 and the mean condition factor was 0.79, similar to the Bras d'Or Lake stock. However, the Isle Madame fish were predominantly in early stages of gonad maturation, indicating a fall spawning stock.

Length-Weight

Length-weight curves for the 1980 and 1981 samples were derived from logarithmic transformation of the equation $W = aL^b$, in which a = y-intercept and b = slope of the length-weight regression line.

1980 $\log W = -6.78832 + 3.67631 \log L$ ($r = 0.94$)

1981 $\log W = -6.73841 + 3.65814 \log L$ ($r = 0.95$)

Since the slopes and y-intercept values for 1980 and 1981 are very similar the curve in Fig. 5 represents a combined fit for the two years. Also shown are the length-

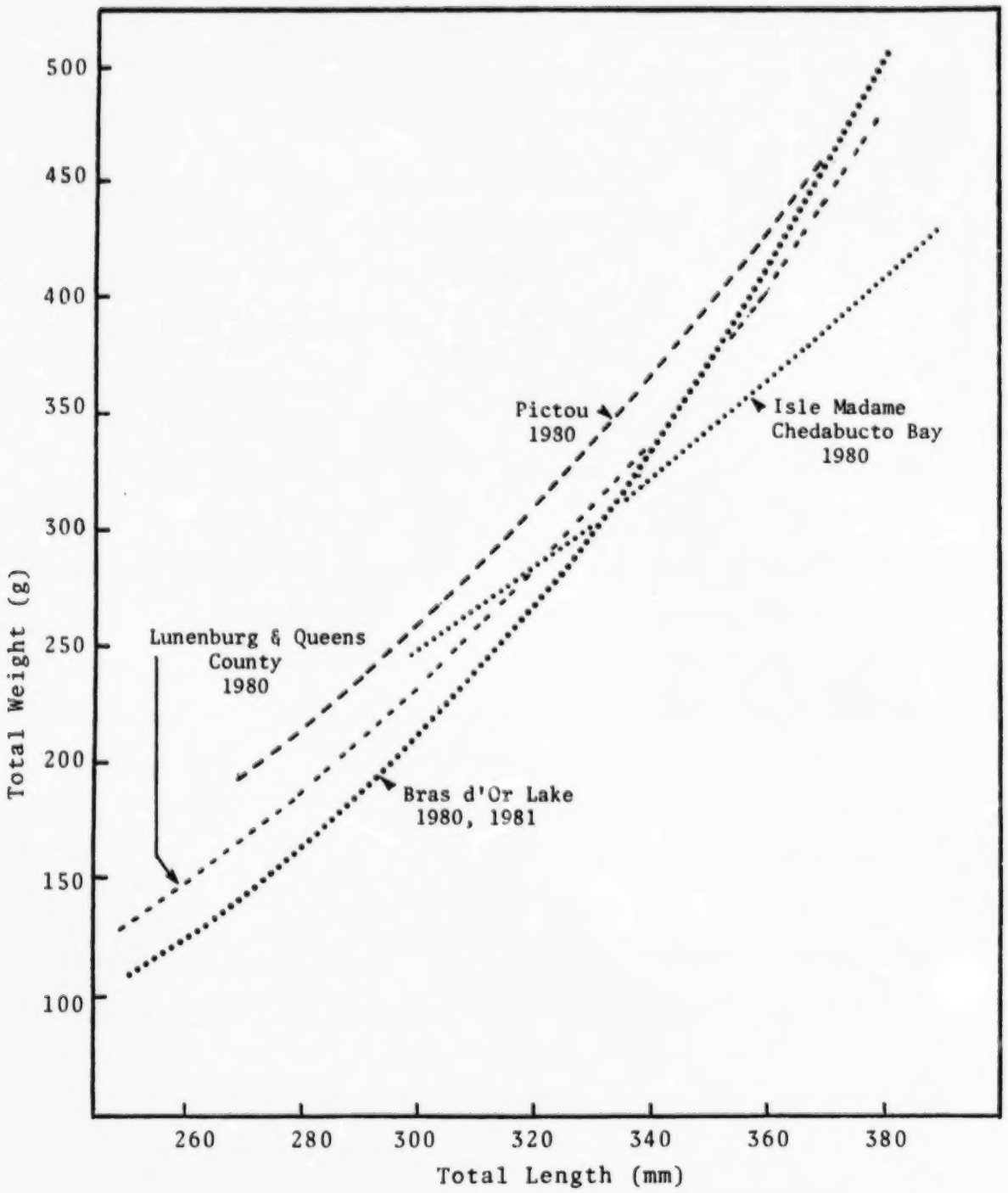

Fig. 5 Length-weight relationship for herring samples from West Bay, Bras d'Or Lake compared to herring samples from the south shore (Lunenburg and Queens Counties), north shore (Caribou-Pictou) and Chedabucto Bay (Isle Madame).

weight curves for 1980 herring samples from the south shore, north shore and Chedabucto Bay. The regression equations for these regions are as follows:

1980 Lunenburg and Queens Counties (N = 644): $\log W = -5.25546 + 3.07479 \log L$ ($r = 0.95$)

1980 Pictou Island (N = 261): $\log W = -4.37678 + 2.73996 \log L$ ($r = 0.81$)

1980 Isle Madame (N = 134): $\log W = -2.80758 + 2.09959 \log L$ ($r = 0.84$)

The differences in the length-weight relationship for these regions is mainly a result of different degrees of gonad maturation. The south shore sample is a composite of sampling from May to September with varying degrees of gonad maturation (stage 2-8). The Pictou Island sample represents sampling during August and September, with a high percentage of pre-spawning fish (stage 5). Sampling from Isle Madame was conducted in May, with fish primarily at an early maturation (stage 3).

Based on the predicted weights from the above equations fish from Pictou Island with a length of 280 mm were approximately 50 g heavier than comparable length fish from the Bras d'Or Lake. At a length of 370 mm there were no significant differences in weight between fish from these two regions. The weight differential between the south shore and Bras d'Or Lake samples was not as pronounced. The Isle Madame sample

showed a positive weight differential for fish from 300 mm - 330 mm relative to Bras d'Or Lake herring. However, for larger fish (340 - 380 mm) there was a progressive weight differential such that at 380 mm length the predicted weight for Isle Madame fish was approximately 94 g less than for comparable length fish from Bras d'Or Lake.

Since the length-total weight relationship reflects the degree of gonad maturation the length-somatic weight relationship has been examined for yearly variation and sex differences. The regression equations for male-female and 1980-81 are as follows:

Bras d'Or Lake

1980 Male Log W = -5.56318 + 3.16166 log L

Female log W = -6.39695 + 3.48485 log L

1981 Male log W = -5.52558 + 3.15001 log L

Female log W = -5.43945 + 3.11044 log L

From the above equations and as shown in Fig. 6 there was no difference in the male length-somatic weight relationship for 1980-81. For female (Fig. 7) herring from the Bras d'Or Lake the slopes of the regression lines for 1980-81 are slightly different but it is unlikely that the difference is statistically significant. The data also indicates that there is no fundamental difference between the sexes concerning the length-somatic weight relationship.

Feeding Intensity

Estimates of the degree of feeding, based on stomach fullness showed that the vast majority of fish were not feeding (Fig. 8). However, there was a difference between

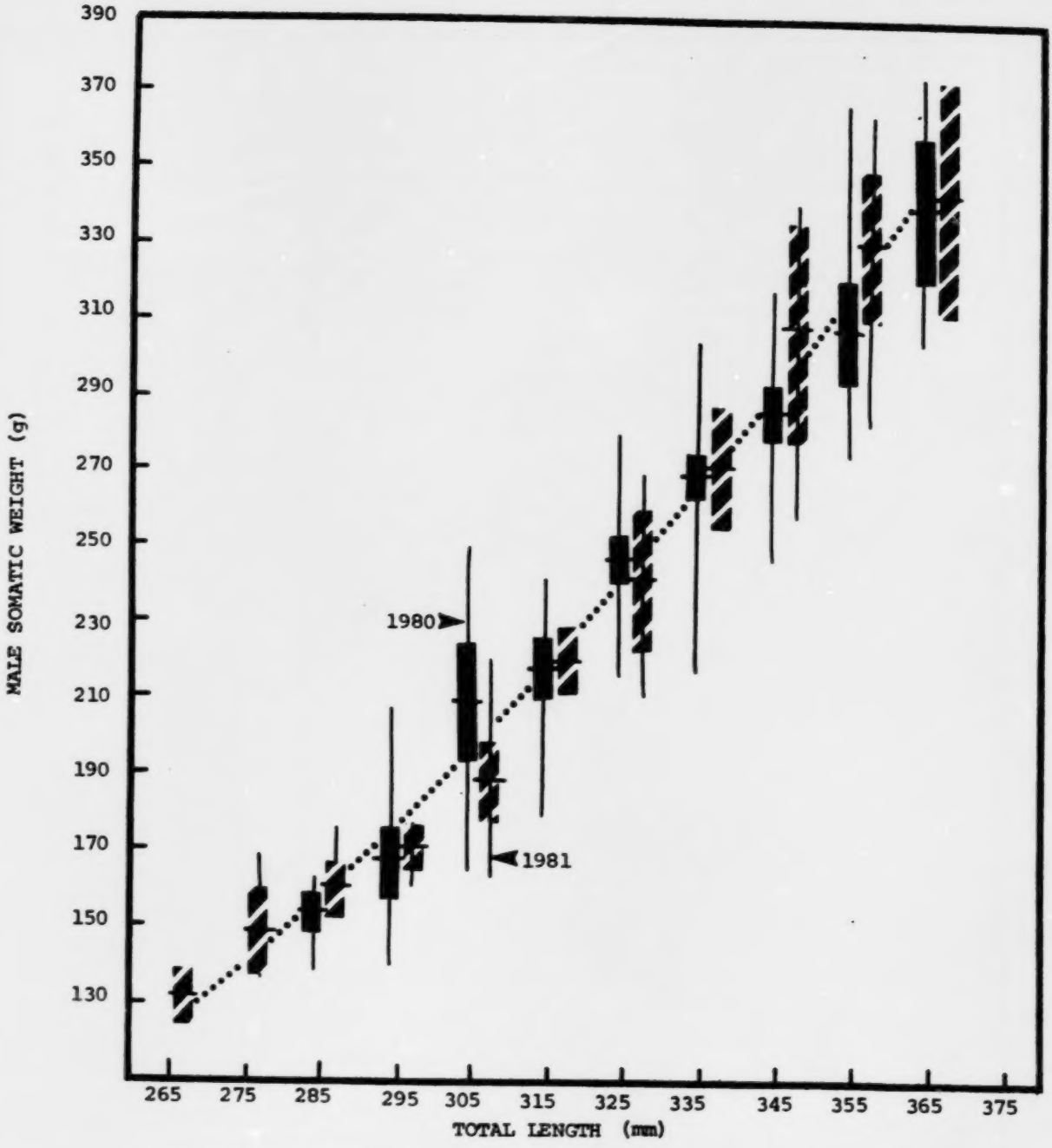

Fig.6 Length-somatic weight relationship for male herring samples from West Bay, Bras d'Or Lake for 1980 and 1981. Statistical symbols: mean-horizontal line; vertical bar-$\pm$ 2 S.E.; vertical line-range. The dotted line represents a fit of the data based on regression analysis and log transformation of length and weight.

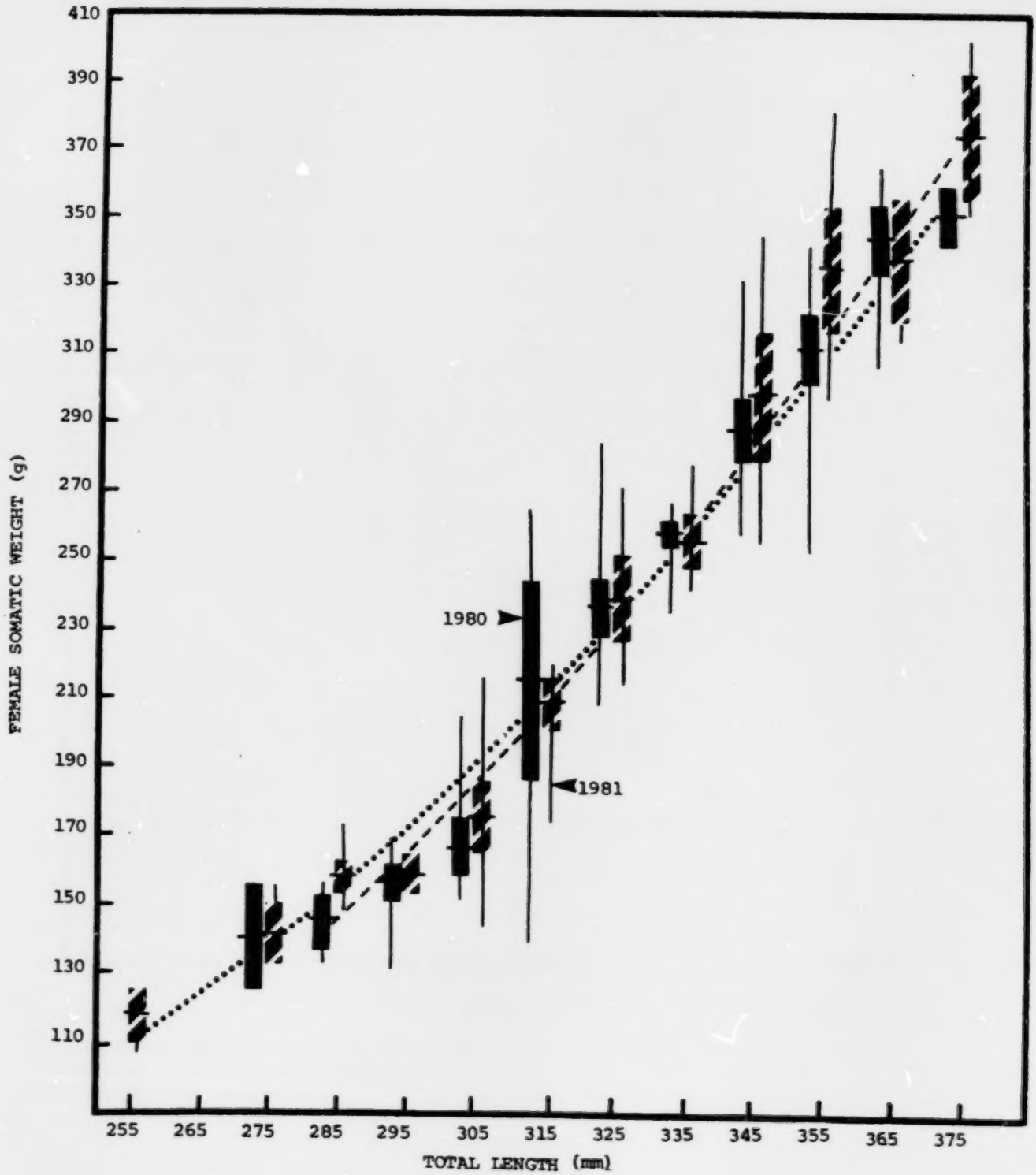

Fig. 7 Length-somatic weight relationship for female herring samples from West Bay, Bras d'Or Lake for 1980 and 1981. Statistical symbols as in Fig.6. The broken and dotted lines represent fits of the data for 1980 and 1981 based on regression analysis and log transformation of length and weight.

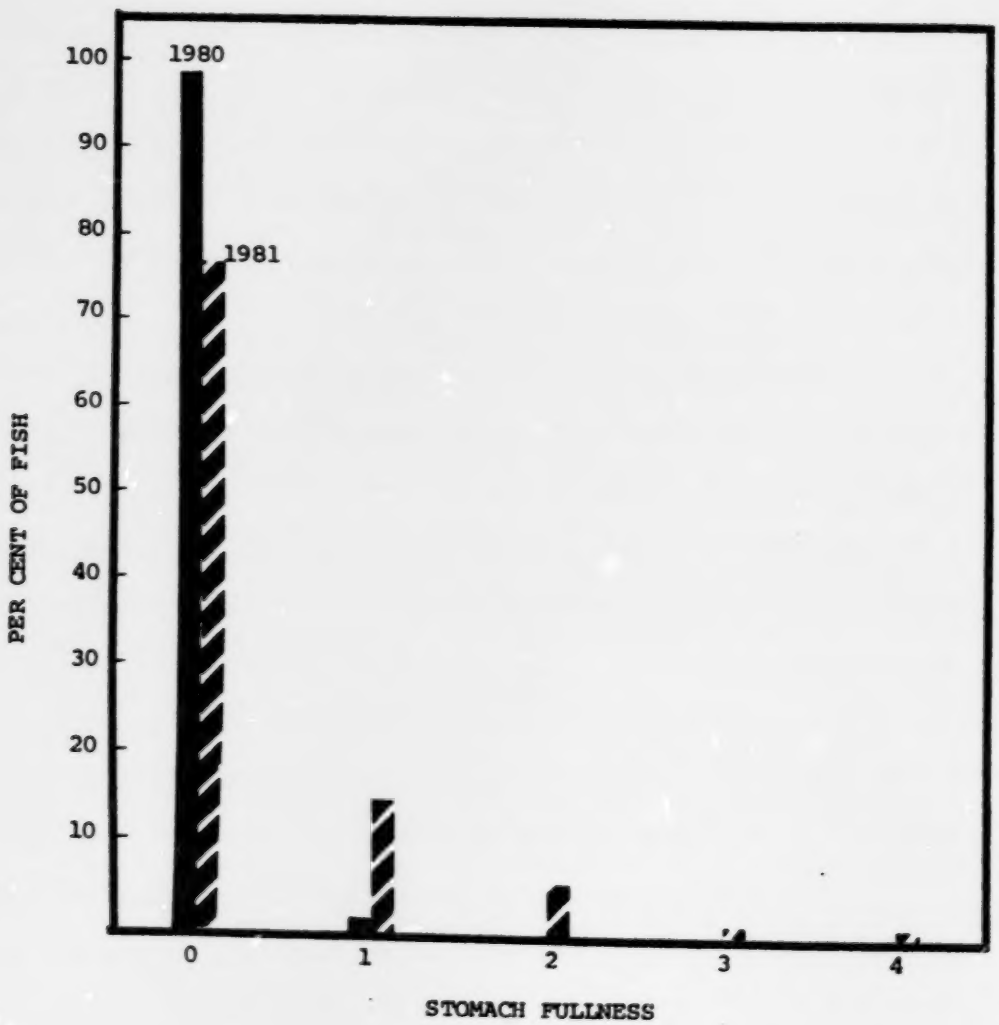

Fig. 8 Degree of stomach fullness in fish sampled from West Bay, Bras d'Or Lake for 1980 and 1981. Stomach fullness was estimated according to the following categories: 0=empty; 1=0-25% full; 2=25-50% full; 3=50-75% full; 4=75-100% full.

1980 and 1981 with 98% of the fish having empty stomachs in 1980 compared to 77% in 1981. At 0-25% fullness only 2% of the 1980 sampled showed this level of feeding but 16% of the fish in 1981 were in this category. Also, in the 1981 sample the stomach fullness levels of 2, 3 and 4 were all evident, though in very small numbers. The different intensity of feeding in 1980-1981 is correlated with earlier sampling dates in 1981 and a less advanced gonad maturation stage for most fish (see maturation section).

Sampling of fish along the Atlantic Coast of Nova Scotia in 1979 and 1980 has shown varying degress of feeding associated with season and gonad maturation. For example, in fish samples from the eastern shore (1979), 41% showed no feeding in May and this increased to 95% by September. The herring stocks in this region spawn in September and October. In fish samples from the south shore in 1980 45% of the fish had a stomach fullness of 0-25% but only 16% of the sample had this level of feeding by September.

The Pictou Island fishery has rather similar parallels to the Bras d'Or Lake fishery since both exploit prespawning-spawning fish. Herring sampled from the Pictou Island region showed consistently low levels of feeding with 92% of the fish having empty stomachs in 1979 and 100% in 1980.

Gonad Maturity

The results of assessing the 1980-81 samples according to gonad maturity (Table III) are shown in Fig. 9 for the combined sexes. In 1980, 77% of the herring were classified

Table III Stages in maturity and the description of the gonads of herring in the various stages according to ICNAF (1964)

Stage	Description
1	Virgin herring. Gonads very small, threadlike, 2-3 mm broad. Ovaries wine red. Testes whitish or grey brown.
2	Virgin herring with small sexual organs. The width of ovaries and testes about 3-8 mm. Eggs not visible to the naked eye but can be seen with magnifying lens. Ovaries a bright red colour; testes a reddish grey colour.
3	Gonads occupying about half of the body cavity. Breadth of sexual organs 1-2 cm. Eggs small but can be distinguished with naked eye. Ovaries orange; testes reddish grey or greyish.
4	Gonads almost as long as body cavity. Eggs larger, varying in size, opaque. Ovaries orange or pale yellow; testes whitish.
5	Gonads fill body cavity. Eggs large, round; some transparent. Ovaries yellowish; testes milkwhite. Eggs and sperm do not flow, but sperm can be extruded by pressure.
6	Ripe gonads. Eggs transparent; testes white; eggs and sperm flow freely.
7	Spent herring. Gonads baggy and bloodshot. Ovaries empty or containing only a few residual eggs. Testes may contain remains of sperm.
8	Recovering spents. Ovaries and testes firm and larger than in virgin herring in Stage 2. Eggs not visible to naked eye. Walls of gonads striated; blood vessels prominent. Gonads wine red colour. This stage passes into Stage 3.

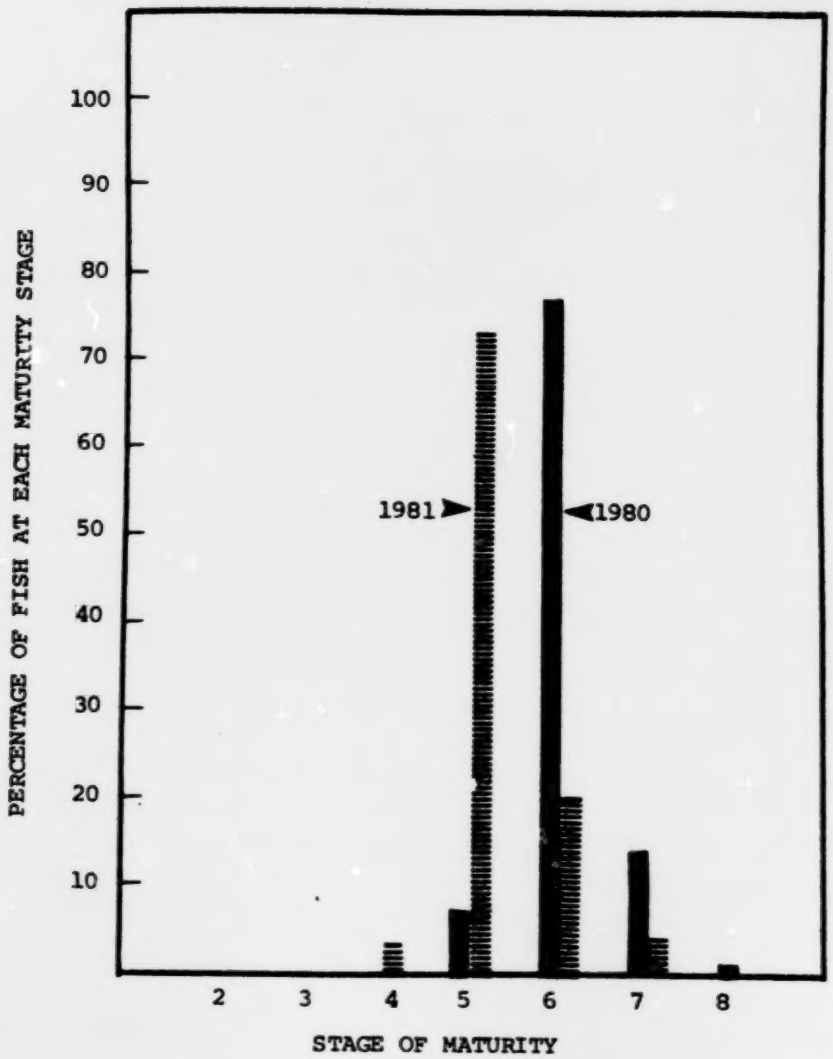

Fig. 9 Gonad maturation of herring sampled from West Bay, Bras d'Or Lake in 1980 and 1981.

as in maturity stage 6, whereas in 1981 only 20% were in this category. In 1981 the majority of herring were in stage 5 (73%) compared to 7% at this stage in 1980. The 1980 sample also contained higher percentages of spent and recovering fish (stage 7 & 8) compared to 1981. There are two factors that may be associated with those findings. Sampling in 1981 was initiated at an earlier date than in 1980. The 1981 sample also included a high number of young fish and these may not have been as advanced in maturation, compared to older fish.

The spring spawning stock of the Bras d'Or Lake contrasts with the predominantly fall spawning stock(s) along the Atlantic coast. Sampling in 1979 and 1980 from various locations on the east and south shore generally showed a progressive trend in gonad maturation from spring to fall.

For samples from Lunenburg and Queens counties in 1980 the June composite sample consisted of the following maturity stage percentages: 2-9%; 3-58%; 4-31; 5-2%. By September the percentage occurrence was: 2-0%; 3-2%; 4-2%; 5-67%; 6-8%; 7-10%; 8-11%.

Perhaps the best comparison is with fish sampled from Isle Madame in May, 1980. The percentage occurrence at each maturity stage was as follows: 3-63%; 4-31%; 5-4%; 6-1%; 7-1%. These fish were then primarily fall spawners, though with small numbers of spring spawners.

Nematode Incidence

As shown in Fig. 10 nematode incidence increased with an increasing fish length. There was some variation for the years 1980-1981 but with a general increase from 0% at

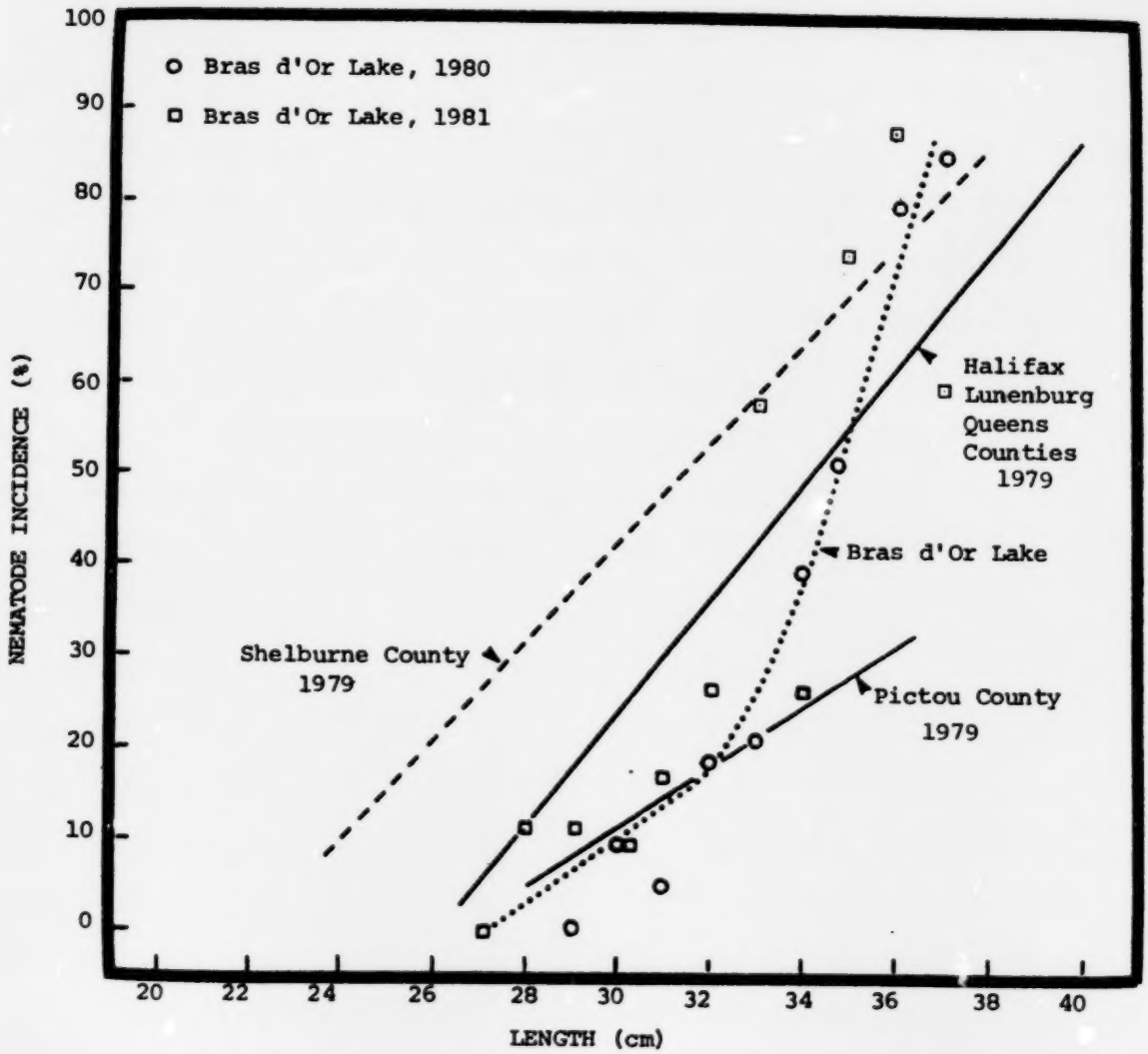

Fig. 10 Percentage nematode incidence relative to fish length for herring from West Bay, Bras d'Or Lake (1980, 1981) compared to incidence levels in herring from the Atlantic coast and Northumberland Strait (Crawford, 1980). The lines for the latter regions are based on regression analysis, whereas the curve for the Bras d'Or Lake has been fitted by eye.

a length of 270 mm to approximately 84% at 360 mm length. Comparison of incidence levels of the Bras d'Or Lake herring with other regions shows that for smaller fish (270-330 mm) the nematode incidence was similar to that found in Pictou County samples for 1979-1980. However, for larger fish (340-370 mm) the values were more comparable to incidence levels in fish sampled along the east and south shore for 1979-1980.

For fish $\geq$ 300 mm total length the 1980 nematode incidence was 33%, and 37% for the 1981 Bras d'Or Lake sample. Sampling of herring in 1979 along the Atlantic coast of Nova Scotia and Northumberland Strait showed the following incidence levels for fish $\geq$ 300 mm length: Halifax County - 53%; Lunenburg and Queens Counties - 43%; Shelburne County 62%; Pictou County 17%. In 1980 sampling the incidence levels were: Halifax County 58%; Lunenburg and Queens Counties - 50%; Pictou County - 32%. The Bras d'Or Lake incidence levels appear to be intermediate between the Atlantic Coast and Northumberland Strait levels of nematode incidence. However, comparisons for fish $\geq$ 300 mm length are complicated by the length-nematode relationship and the length-frequency composition of the samples.

Meristics

Frequencies of gill raker number, dorsal, pectoral and anal fin ray number from Bras d'Or Lake spring spawning herring and East Chezzetcook autumn spawning herring were compared using an unpaired independent statistical, t-test. Fig. 11 illustrates the mean number of meristic elements

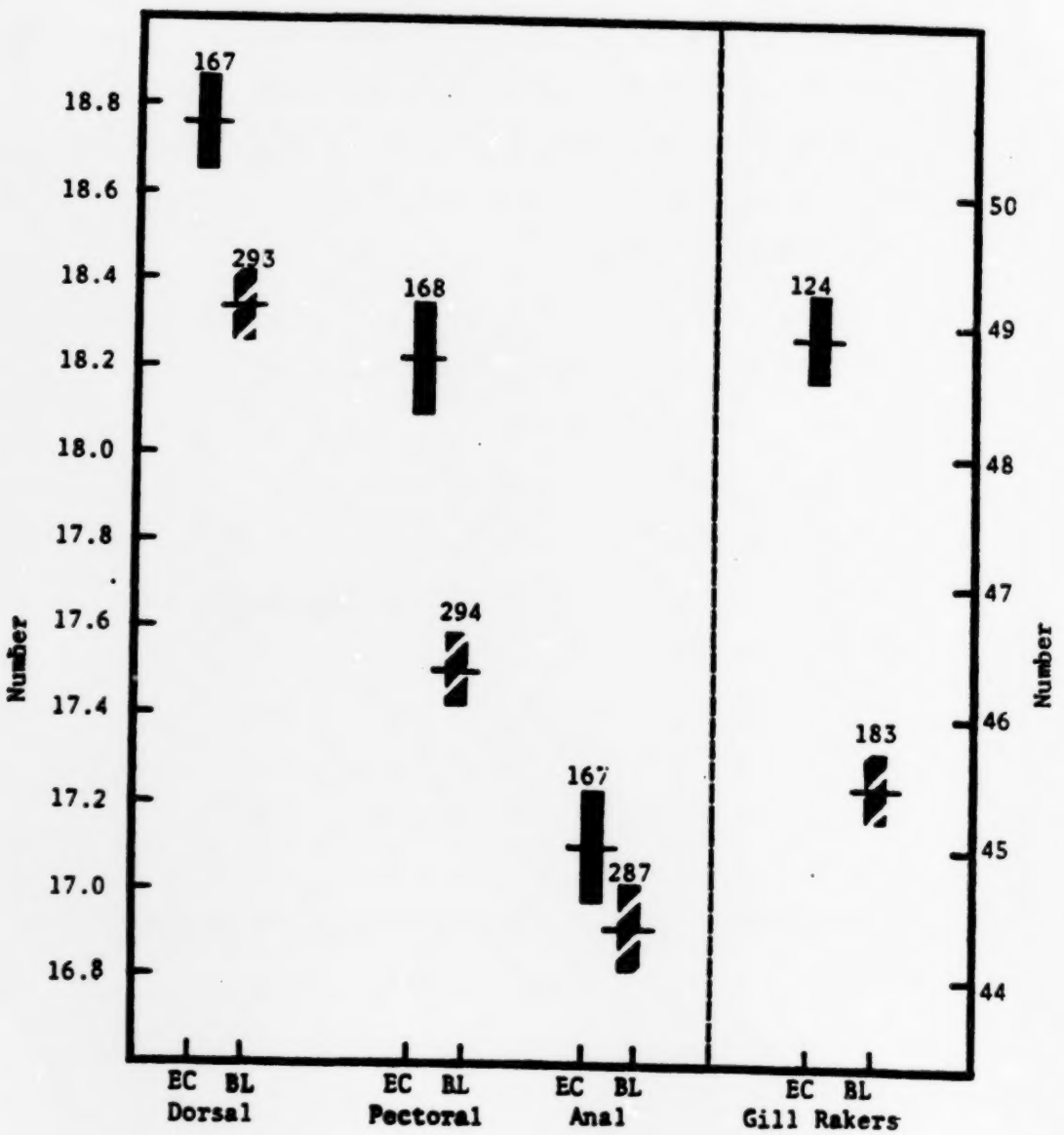

Fig. 11 : Mean number of dorsal, anal and pectoral fin rays and gill rakers for spring spawning fish from Bras d'Or Lake (B.L.) and autumn spawning fish from East Chezzetcook (E.C.) for the year 1980 (Horizontal line - mean; verticle bar - $\pm$ 2 Std. Error).

Table IV : Test for significance of differences of the mean number of dorsal fin rays, pectoral fin rays, anal fin rays and gill rakers between East Chezzetcook (.E.C.) and Bras d'Or Lake samples for the year 1980.

Area	N	Mean	Std. Dev.	Std. Error	Range min.	Range max.	T value	Significance
			Number of Dorsal Fin Rays					
E.C.	167	18.76	0.711	0.055	17	21	6.16	**
B.L.	293	18.34	0.706	0.041	16	22		
			Number of Pectoral Fin Rays					
E.C.	168	18.22	0.815	0.063	16	20	9.82	**
B.L.	294	17.50	0.724	0.042	15	19		
			Number of Anal Fin Rays					
E.C.	167	17.09	0.856	0.066	15	20	2.17	*
B.L.	287	16.91	0.860	0.051	15	20		
			Number of Gill Rakers					
E.C.	124	48.92	1.83	0.164	44	54	16.99	**
B.L.	183	45.47	1.69	0.125	40	51		

(N.S. - not significant; **-$p<0.01$; *-$0.05>p>0.01$)

for the two sampling regions. The mean number of fin rays and gill rakers was significantly different between the two regions (Table IV) and in all meristic characters the mean number was greater for the East Chezzetcook sample. Previous studies (Parsons, 1973) have not shown a significant relationship between fin ray number and length so that length was not considered to be a source of variation. Regression analysis of gill raker number and total length proved to be non-significant.

Fecundity

Fecundity estimate ranged from 47,442 eggs for a fish of 316 mm length to 165,227 for a 360 mm specimen. Fig. 12 illustrates the individual values for fecundity on length and the regression curve. The curvilinear relation was best fitted by applying a logarithmic transformation to the data. The parameters for the length and weight equations are given in Table V. Predicted fecundity values and observed values for a given length are shown in Table VI.

The resulting fecundity-length curve incidates that fecundity increases at a rate greater than the cube of body length. Fig. 12 shows that fecundity varies considerably for any one length group. This would appear to be partly a result of gonad maturation, since the majority of stage 6 fecundity estimates were generally lower than comparable fecundity values for fish at stage 4 and 5 (Fig. 12). Due to the problems of using stage 6 gonads for fecundity estimates these were excluded and regression analysis based only on

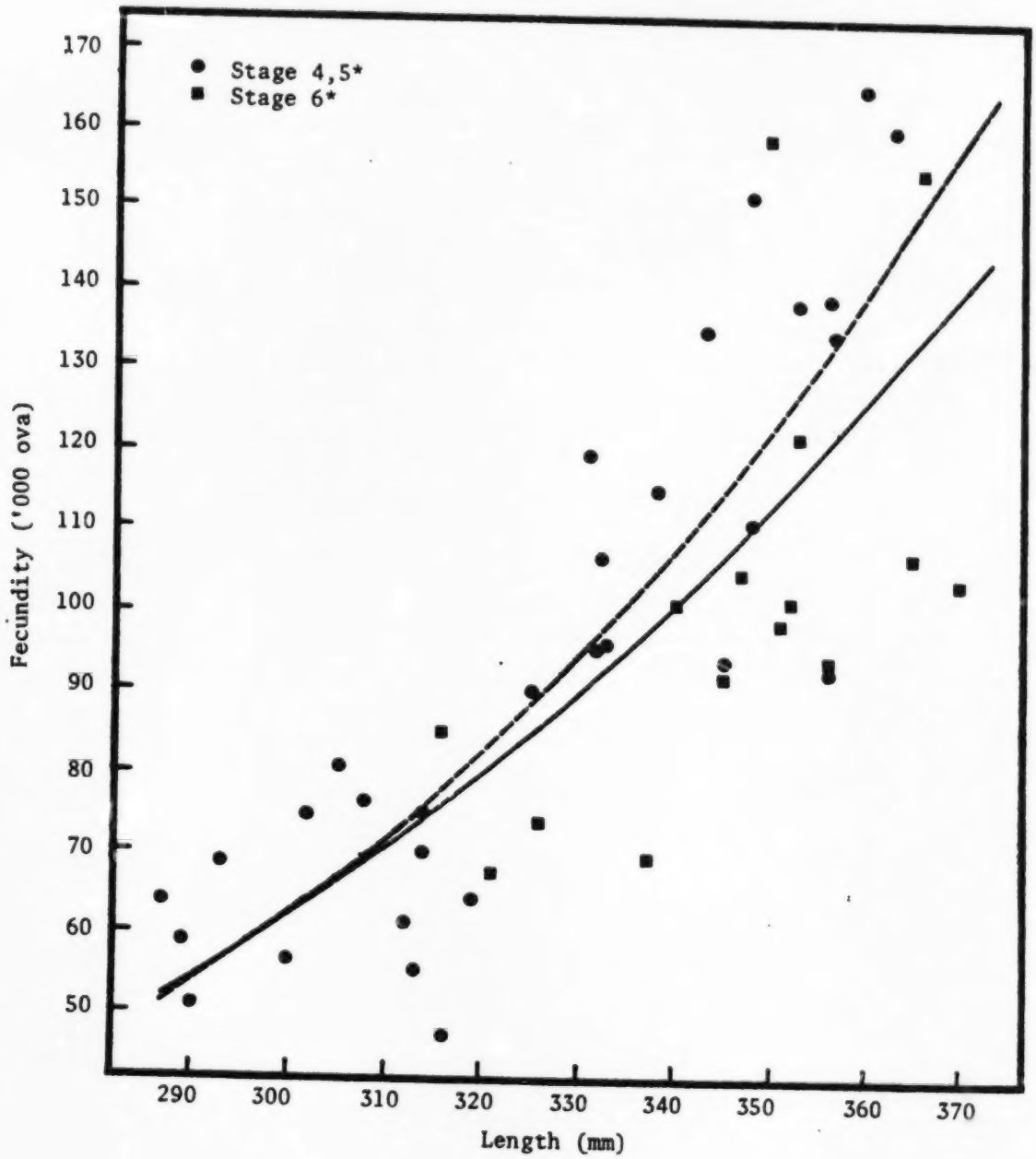

Fig. 12: Scatter diagram and fitted regression curve of fecundity and length relation of Bras d'Or Lake, West Bay herring samples (Solid line - regression curve of stage 4,5 and 6 estimates; Dotted line - regression curve of stage 4 and 5 estimates).

*ICNAF, 1964

Table v : Relations between log fecundity and log length and between log fecundity and log weight of spring spawning herring from the Bras d'Or Lake, West Bay area.

No. of fish	Maturation stage*	Regression coefficient, b	Intercept, log a	Correlation coefficient, r
		Log Fecundity and Log Length (mm)		
45	4,5,6	3.82	-10.80	0.81
30	4,5	4.37	-13.90	0.86
		Log Fecundity and Log Weight (g)		
45	4,5,6	1.01	5.62	0.86
30	4,5	1.15	4.85	0.92

*ICNAF, 1964

Table VI : Mean fecundity estimates ('ooo) and predicted values by length group of spring spawning Bras d'Or Lake (West Bay) herring and predicted values for spring spawning herring of the Canadian Maritimes area reported by various authors.

Length group (mm)	Bras d'Or Lake (West Bay)[a] Observed Range	Bras d'Or Lake (West Bay)[a] Observed Mean (N)	Bras d'Or Lake (West Bay)[a] Predicted Values	Southwest Nfld.[b] Predicted Values	Fortune Bay Nfld.[b] Predicted Values	Placenta Bay Nfld.[b] Predicted Values	Southern Gulf of St. Lawrence[c] Predicted Values
270			42.0	38.5	32.3	43.7	43.4
280	57.4- 63.9	60.6(2)	49.1	45.2	38.8	50.5	48.3
290	51.1- 69.0	60.1(2)	57.1	52.8	46.4	58.0	54.7
300	56.5- 80.6	72.0(4)	66.0	61.3	55.0	66.4	61.3
310	47.4- 75.0	62.2(6)	76.3	70.9	64.9	75.5	69.7
320	- -	90.0(1)	87.1	81.6	76.2	85.7	77.8
330	95.4-119.7	106.5(5)	99.5	93.5	89.1	96.9	87.8
340	94.3-152.1	123.1(4)	113.1	106.7	103.6	108.1	97.9
350	93.1-139.5	126.5(4)	128.2	121.3	120.0	122.2	109.9
360	160.5-165.2	162.9(2)	144.7	137.1	138.4	136.6	
370			162.9	155.2	159.0	152.4	
380			182.7	174.0	182.0	169.4	

a (this report: observed and predicted values represent stage 4 and 5 gonad estimates
b (Hodder 1972)
c (Messieh 1976)

stage 4 and 5 gonads. The slope increased from 3.82 to 4.37 and correlation coefficient increased from 0.81 to 0.86.

The relation between fecundity and total fish weight was also best represented by a logarithmic transformation of the data giving the equation log Fec = log a + b log W. With the exclusion of stage 6 gonads the slope increased from 1.01 to 1.15 and correlation coefficient 0.86 to 0.92 (Table V).

Egg and Larval Survey, Ross Cove

Spawning

The time of spawning was estimated to have had occurred on the night of April 8, 1981 in Ross Cove, West Bay, based on two observations. The water over the spawning bed was whitish on April 9th, presumably due to the concentration of male sperm, and egg samples were in the first stage of development.

Spawning Bed Characteristics

Physical

The spawning bed was relatively small (~ 100 m^2) and located at the upper end of Ross Cove (Fig. 2). Egg deposition occurred in shallow depths of approximately 0.25 - 0.75 m, dependent on bottom topography and tide level.

Water temperature fluctuated considerably throughout egg development and hatching (Table VII), ranging from 4.5 - 13 C (surface). The most extreme change occurred one day after spawning when the temperature declined from 13-6 C. The temperature then remained relatively low,

Table VII Physical and biological characteristics of the spawning bed at Ross Cove, West Bay, Bras d'Or Lake 1981.

Date	Time	Water Temp. (C)	Salinity (°/oo) Depth - 0.5m	No. eggs/g algae (eelgrass)	Egg Samples unhatched % (N)	dead %(N)	hatched % (N)	Larval Catch (sieve) mean no. (10 hauls)
09/04/81	1400	13 surface	-	2,090	-	-	-	-
10/04/81	1300	6 surface	16.0 bottom	963	-	-	-	-
14/04/81	1230	9 surface	19.4 bottom	292	91.5(582)	8.5(54)	0(0)	-
20/04/81	1300	6 surface	-	-	-	-	-	-
21/04/81	1600	5.5 surface	16.0 bottom	-	-	-	-	-
27/04/81	1415	9 surface	19.4 bottom	290	87.0(408)	6.4(30)	6.6(31)	1.0
28/04/81	1015	4.5 surface 6.5 bottom	17.4 bottom	309	84.1(143)	14.1(24)	1.8(3)	8.1
29/04/81	1210	7 surface	1.8 bottom	202	65.9(239)	12.8(48)	21.3(78)	21.6
30/04/81	1020	8 surface	19.6 bottom	55	54.5(96)	27.3(48)	18.2(32)	24.1
01/05/81	1015	6 surface	19.6 bottom	11	46.2(50)	24.0(26)	29.8(32)	28.2
02/05/81	1300	9.5 surface	15.6 bottom	0	-	-	-	1.1
04/05/81	1319	7 surface	9.6 bottom	-	-	-	-	0
05/05/81	1631	8 surface	6.8 bottom	-	-	-	-	0
06/05/81	1530	11 surface	16.2 bottom	-	-	-	-	0
	$\bar{x}$ 7.8±2.3(14)		$\bar{x}$ 14.8±5.7(12)					

for approximately three weeks after spawning. During some of the colder nights ice formed over the cove. Surface temperatures were taken but may not reflect the bottom temperature since on April 28th the surface temperature was 4.5 C and 6.5 C at 0.3 m depth. The thermocline was presumably facilitated by a salinity stratification. The average surface temperature during the egg and hatching period was 7.6 $\pm$ 2.4 C. Salinity measurements over the spawning bed also fluctuated considerably during egg development and hatching, ranging from 1.8 $^{o}/_{oo}$ to 19.6 $^{o}/_{oo}$ (Table VII). This can probably be attributed to variable influx of freshwater from White Brook combined with tidal flux.

Egg Deposition

The eggs were deposited chiefly (~ 80%) on eelgrass (Zostera marina), with smaller numbers on sea lettuce (Ulva sp.) and Ruppia maritima. Eelgrass samples taken at the spawning site just after spawning (April 9th) showed a high concentration of eggs with approximately 2,000 eggs/g seaweed (Table VII). Strands of eelgrass were completely covered in layers of eggs. No attempt was made to quantify egg density over the spawning site but visual observation indicated a decrease in concentration towards the periphery of the spawning bed. Egg density in the centre of the spawning bed decreased with time (Fig. 13A) and appeared to stabilize at approximately 290 - 300 eggs per/g algae to the time of hatching.

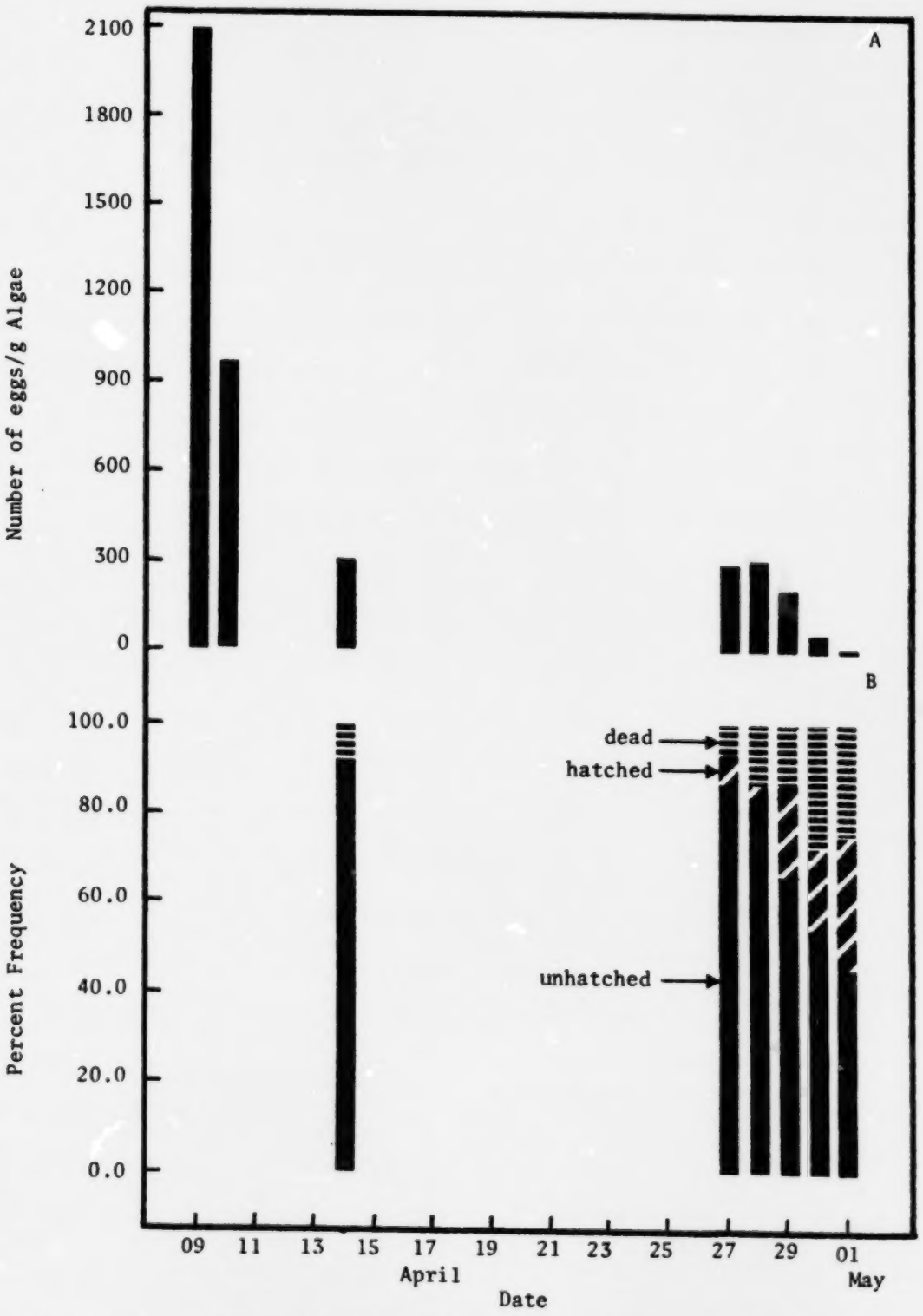

Fig. 13 A. Density of herring eggs on algae at the spawning site in Ross Cove during the incubation and hatching periods.

Fig. 13 B. Percentage occurrence of unhatched, hatched and dead eggs during the incubation and hatching phases.

Egg Mortality

Sampling of eggs on April 14th, 6 days after fertilization, showed that 8.5% of the eggs were dead and at the beginning of hatching (April 27th) the egg mortality was 6.4% (Fig. 13B). During the hatching period percentages of dead eggs progressively increased but this was primarily due to an increasing number of egg capsules disintegrating (hatched eggs) and therefore not included in the total number. Similarly the percentages of hatched and unhatched eggs would be underestimated from April 27th to May 1st. This is also evident from the sharply declining eggs/g algae during the hatching period. (Fig. 13A).

Larval Density and Dispersal

Concentrations of larvae over the spawning bed increased dramatically from 122 larvae/m^3 at the beginning of hatching to 4,655 larvae/m^3 by May 1st (Fig.14A; Table VIII). On May 2nd the larval concentration had sharply declined to 40 larvae/m^3 and 0 by May 4th.

Larval dispersal from the spawning site was evident from sampling at RC_2. Concentrations of larvae increased during the hatching period but with the peak catch occurring on April 30th, one day in advance of the peak concentration at RC_1 (spawning site). Larval dispersal in Ross Cove appeared to be due primarily to currents generated by tidal and meteorological conditions and this may account for the discrepancy in modal concentrations between RC_1 and RC_2.

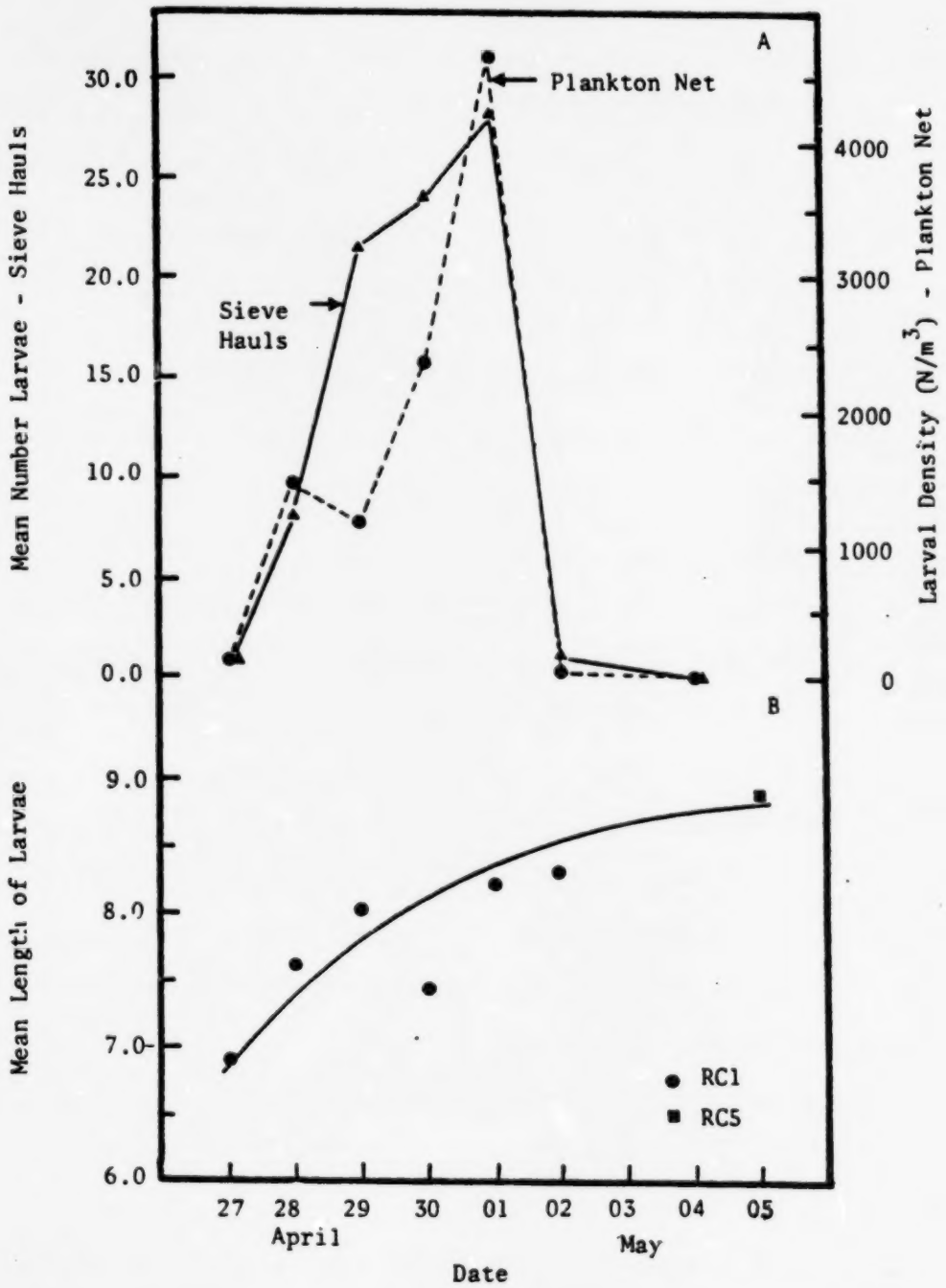

Fig. 14 A. Estimates of herring larval density during the hatching period in Ross Cove (RC1) based on the mean number of larvae per 10 sieve hauls and the number/m^3 using a 0.5 m plankton net.

Fig. 14 B. Mean length of larvae samples at RC1(●) and RC5 (■), Ross Cove during the hatch and post hatch periods.

Table VIII Larval density at Ross Cove Stations (RC_1 - RC_5) based on vertical net hauls during the hatching period.

Date	Stations Larval Density (N/m^3)				
	RC_1 (0.5m)*	RC_2 (1.0m)	RC_3 (4.5m)	RC_4 (4.5m)	RC_5 (6.0m)
27/04/81	122.2	-	-	-	-
28/04/81	1,477.0	15.8	0	0	0
29/04/81	1,171.4	157.5	0	0	0
30/04/81	2,352.9	525.5	0	12.4	0.9
01/05/81	4,655.0	105.0	1.1	1.1	0
02/05/81	40.7	10.5	1.3	0	0
04/05/81	0	5.3	2.3	3.4	0.9
05/05/81	0	0	0	0	0
06/05/81	0	0	0	0	0

* vertical net haul depth

Considerably lower larval densities were evident at RC_3, RC_4 and RC_5. By May 5th and 6th the larval catch had declined to 0 at all stations, based on vertical net hauls. However, a horizontal tow at RC_5 on May 5th established that larvae were present, though the density was not quantified (Table IX).

Exploratory horizontal and vertical tows were also conducted at various locations within West Bay (Table IX). Only three of these tows indicated the presence of herring larvae: Ross Cove, MacLeod Cove and North Cove. These results suggest that, herring spawning was of a very low intensity in 1981 and that dispersal from Ross Cove and North Cove into West Bay was low in magnitude.

Larval Growth

A measure of short term growth was obtained for herring larvae from April 27th to May 5th. Daily length frequency and mean total length are shown in Table X for samples collected at the spawning site (RC_1) and RC_5. Generally there was an increase in length for larvae sampled during the period of hatching (Fig. 14B), with the exception of larvae sampled on April 30th. However, after April 27th sampling includes both recently hatched larvae and later stages of development (Table X) so that the mean values tend to underestimate the daily growth. Using the initial mean length of 6.94 mm for larvae sampled at the beginning of the hatchery period and the mean length of 8.89 mm for larvae sampled on May 5th at RC_5 gives a growth of 1.95 mm in 8 days

Table IX Exploratory plankton net tows in West Bay for herring larvae.

Date	Location	Temp. (C)	Type of Tow	Duration (min)	Depth (m)	Herring Larvae (N)
05/05/81	Ross Cove (RC_5)	-	Horizontal (surface)	8	-	17
05/05/81	MacLeod Cove	7.5	Vertical	-	2.0	1
06/05/81	North Cove (inner)	9.0	Vertical	-	1.5	1
08/05/81	North Cove (outer)	5.0	Vertical	-	-	0
08/05/81	Ross Cove (outer)	6.5	Vertical	-	5.0	0
08/05/81	Widow Pt.	5.0	Horizontal (surface)	32	-	0
12/05/81	Marble Mtn. Channel	10.0	Horizontal (surface)	13	-	0
12/05/81	Little Harbour	12.0	Horizontal (surface)	13	-	0
12/05/81	Rook Island	10.0	Horizontal (surface)	-	-	0
13/05/81	Johnson Cove	8.0	Horizontal (surface)	19	-	0
13/05/81	Militia Is. to Militia Pt.	7.0	Horizontal (surface)	26	-	0
13/05/81	Grammond Is. to Spruce Pt.	8.0	Horiztonal (surface)	-	-	0

Table X Length frequency of larvae relative to days from spawning and sampling location.

Days from Spawning (Station)	Stage*	No. at each length (mm) 6	7	8	9	Total	Mean Length mm±IS.D.
19(RC_1)	1a	7	4	1		12	6.94±0.62
20(RC_1)	1a	3	27	10		40	7.61±0.41
21(RC_1)	1a,1b		9	30	1	40	8.02±0.48
22(RC_1)	1a(35%) 1b(65%)	6	35	5		46	7.43±0.46
23(RC_1)	1b		14	27	3	43	8.21±0.55
24(RC_1)				4		4	8.27±0.37
27(RC_5)	1b(6%) 1c(94%)		1	10	6	17	8.89±0.55

*Stage based on classification system of Doyle (1977)

or 0.24 mm/day.

General Observations on Spawning in North Cove, 1980

Based on information received from commercial fishermen, herring had spawned in North Cove on the night of April 19, 1980. Later examination of the spawning bed showed it to be approximately 3,000 m^2 in size (Fig. 2). The depth of the spawning bed ranged from 0.3 - 1.5 m with the greatest density of eggs in the shallow part of the cove. The eggs were deposited primarily on eelgrass (Zostera marina) and the bottom substrate in the cove was a mixture of sand and silt.

Though not specifically measured, larval hatching was evident on May 6th and with a heavy concentration of larvae observed on May 7th and 8th in the water above the spawning bed.

Surface water temperature ranged from 7.5 - 10C during the observed period of hatching. Salinity measurements on May 15th gave a surface level of 21.0 $^{o}/oo$ and 22.2 $^{o}/oo$ at 0.5 m depth which indicates that North Cove does not receive the degree of freshwater input as recorded in Ross Cove. North Cove is also considerably more open to the main section of West Bay.

Discussion

Adult Biology

Comparison of the spring spawning herring of the Bras d'Or Lake with fall spawning stocks of the Atlantic Coast of Nova Scotia and Northumberland Strait has shown differences in growth, gonad maturity, feeding and nematode incidence. The different growth pattern indicates that a portion of the Bras d'Or Lake stock matures at age 3, based not only on the fact that all age 3 fish sampled were mature but also reflected in the lower length-at-age values for ages 4-11, compared to fall spawners. The degree of maturity at age 3 is unknown but may be significant compared to fall spawning stocks. Messieh (1976) found that spring spawners reached sexual maturity at a shorter length and younger age than autumn spawners of the southern Gulf of St. Lawrence. Various studies have shown a slightly lower growth (length-at-age) in spring spawners compared to fall spawners (Tibbo, 1957; Parsons and Hodder, 1975; Cote and Powles, 1978). However, they did not find a reversal of this pattern at age 3 as presently recorded. Aging methodology may account for this difference, since the inclusion of the otolith nucleus in the aging procedure depends on the spawning season. Length and age-at-maturity may not only be correlated with spawning season, but also with stock abundance. Anthony and Waring (1980) recorded yearly changes in length and age-at-maturity in herring from Georges Bank and Gulf of

Maine, which appeared to be correlated with stock abundance.

The length-weight relationship showed stock differences which have been interpreted as due primarily to varying degrees of gonad maturation. However, there may be as well differences in the weight of the gonad relative to the somatic weight for prespawning spring and autumn spawners. Messieh (1976) reported a significantly higher mean gonad index (G/L^3) in spring spawners of the Gulf of St. Lawrence compared to autumn spawners. In addition, spring and autumn spawners differ in their seasonal fat content. Parsons and Hodder (1975) found that fat content in spring spawners decreased from 15% in December to a low of 10% in April whereas autumn spawners had an average of 12% fat in December which declined to 6% in April.

The length-somatic weight relationship failed to establish either yearly differences (1980-1981) or sex differences for the Bras d'Or Lake herring. On the latter point McGurk et al. (1980) found a similar fat content in male and female spring spawners from Newfoundland waters. This indicated a similar partitioning of energy into somatic growth for male and female, though there were differences in gonad lipid content.

The incidence and intensity of herring infestation with the larval nematode, Aniskasis simplex (Beverley-Burton et al, 1977) has been used as a possible means of identifying maritime herring stocks (Sinderman, 1961; Parsons and Hodder, 1971; Hodder and Parsons, 1971 a, b). As noted in the present study the size-nematode relation-

ship for Bras d'Or Lake herring differs from that for herring stocks along the Atlantic Coast of Nova Scotia and Northumberland Strait. The causal reasons for regional differences in nematode incidence are poorly understood since our knowledge of the life cycle of Aniskasis simplex is incomplete. The adult and preadult worms have been recorded from a number of whales and seals (Davey, 1971; Margolis and Dailey, 1972; Parsons and Hodder, 1971) but, little quantitative information exists on their predation activity or degree of Aniskasis infestation. Less is known about the intermediate plankton host though several authors have reported Aniskasis sp. from the haemocoel of euphausids, particularly Thysanoessa sp. (Kagei, 1968; Oshima et al., 1969; Smith, 1971). The low level of incidence in small fish from Bras d'Or Lake compared to the much higher incidence in large fish suggests that there may be different regions of feeding for these fish. Perhaps the young fish remain within the Bras d'Or Lake for summer feeding, whereas the older fish may move out of the Lake into the Atlantic for summer feeding.

The meristic counts of Bras d'Or Lake herring were lower for all meristic characters than those of samples from autumn spawning herring from East Chezzetcook. However, there were differences in statistical significance and in descending order the greatest difference was observed for gill rakers, pectoral fin rays, dorsal fin rays and anal fin rays. Parsons (1973) and Messieh and Longmuir (1978) also observed that gill rakers and pectoral fin rays were

the best characters for distinguishing between herring populations.

Scott (1975) studied the meristics of autumn spawning herring from 10 different areas (Bay of Fundy - Chaleur Bay) and spring spawning stocks from the Bras d'Or Lake, Northumberland Strait and Chaleur Bay. He observed, that from all areas and for all meristic characters, there were only two from which the Bras d'Or Lake herring were not significantly different: vertebrae of spring spawners in Northumberland Strait and dorsal rays of herring from Chedabucto Bay. He concluded that the Bras d'Or Lake herring constituted a population distinct from spring and autumn spawners from all other regions. Differences exist between the results of the present study and those of Scott for the Bras d'Or Lake. He did not disclose his method of counting the meristic elements and approximately 60% of his samples were taken after the spawning period. Also both studies were executed in different years. It is for these reasons that meaningful comparisons between the two studies are difficult to make.

In general, Bras d'Or Lake herring exhibit lower meristic counts than other spring and autumn spawners. This may be a genetic difference or may be related to environmental conditions at the time of egg and larval development. It is well documented that the formation of the meristic elements is influenced by such environmental factors as water temperature, salinity, oxygen concentration, and possibly light intensity and duration.

Observations of the spawning bed in North Cove, 1980 and Ross Cove, 1981 indicated that the eggs develop in very shallow water. Water temperature would probably increase more rapidly in spawning areas of shallow water, under normal climatological conditions. Increasing temperature, combined with other factors such as low salinity and possibly high light intensity could conceivably result in the formation of low numbers of meristic elements. The period during development when the number of elements is determined is termed the "sensitive period" (Taning, 1952). This period for herring may extend for several days after hatching (Blaxter, 1957). Vertebral number is determined relatively early in development. The fin rays are the most labile and are the last to be determined (Hempel and Blaxter, 1961). An interesting long-term study would be to relate meristic counts of year classes to environmental conditions at the time of early development.

In herring fecundity studies exponents ranging between 3 and 5 have been observed for the relation of fecundity against length. Hodder (1972) determined exponents of 4.03, 4.49 and 4.88 for spring spawners from the areas of southern Newfoundland which compares with 4.37 determined in this study. Predicted fecundity estimates for Bras d'Or Lake herring are in close agreement with those determined by Hodder (Table VI). Messieh (1976) estimated an exponent of 3.75 for the length-fecundity relationship of spring spawning herring from the southern Gulf of St. Lawrence.

His predicted estimates were lower, for fish > 310 mm, than estimates derived for spring spawning herring of southern Newfoundland (Hodder, 1972) and Bras d'Or Lake (Table IV). The estimates of fecundity of Bras d'Or Lake herring are approximately 25-30% lower than estimates for autumn spawning herring of the Canadian Maritime area reported by Perkins and Anthony (1969), Hodder (1972) and Messieh (1976).

Information on fecundity and abundance of herring from Georges Bank has shown that fecundity varies inversely with the population abundance of its own year class. (Shultz, 1974; Anthony and Waring, 1980). Available data suggests that fish populations reduce fecundity in response to a reduction of growth in weight (Williams, 1964; MacKay and Mann, 1969). Determinations of fecundity of Bras d'Or Lake herring each year could serve as a useful index of yearly changes in the condition of the population.

Early Life History

The spawning bed in Ross Cove appears to be one of the shallowest on record for the Atlantic coast. Tibbo et al. (1963) studied a spawning bed in Chaleur Bay of a spring spawning stock and reported a depth range of 1.3 - 6 m. A similar type of spring spawning bed has recently been assessed in Miramichi Bay with depths ranging from 0.9-4.3 m (Pottle et al., 1980).

The shallow spawning beds of spring spawners is in contrast to the generally deeper spawning depths of fall spawning stocks. Cooper et al. (1975) recorded depths of 35-50 m for autumn spawners on Jeffreys Ledge, Gulf of Maine.

On Georges Bank Caddy and Iles (1973) made observations on a spawning bed at a depth of 50 m. For the Trinity Ledge of southwest Nova Scotia, McKenzie (1964) reported spawning depths of 11-13 m. In interviews conducted with fishermen from along the Atlantic Coast of Nova Scotia (Cape Breton-Digby Counties) the most commonly mentioned depth of spawning was 18-27 m (Crawford, 1979).

The substrate for egg deposition varies widely for spawning stocks in the Northwest Atlantic. On Georges Bank the spawning substrate consisted of gravel (Caddy and Iles, 1973). The spawning substrate on Jeffrey's Ledge also consisted of rock and gravel but with red algae coverage, which formed the major site of egg deposition (Cooper et al. 1975). McKenzie (1964) found egg deposition on sand and gravel for the spawning bed on Trinity Ledge, though in a nearby unsurveyed spawning site the eggs were deposited on Desmarestia aculeata. In the shallow water spawning beds of the Gulf of St. Lawrence egg deposition is associated with dense algal coverage. In studies on a spawning bed in Chaleur Bay Tibbo et al. (1963) found egg deposition on Phyllophora membranifolia and Laminaria sp. in the deeper waters but in shallower waters the vegetation was mainly Chondrus crispus, Fucus evanescens and Ascophyllum nodosum. In Miramichi Bay spawning was associated with Chondrus crispus, Palmeria palmata, Phyllophora sp and Fucus sp, being somewhat similar to the earlier study in Chaleur Bay (Pottle et al., 1980).

In the present study eelgrass (Zostera marina) was the main vegetation for egg deposition though with Ruppia maritima and Ulva utilized as well. Tibbo et al. (1963) found eelgrass near the spawning site in Chaleur Bay but the egg deposition did not extend much onto this vegetation. It is interesting to note that the Pacific herring (Clupea pallasia) also spawns on a variety of algae (Hart and Tester, 1934; Haegele et al., 1979). In the Strait of Georgia red algae was the most commonly utilized vegetation for spawn deposition (Haegele et al., 1981) but in other regions the sea grasses (eelgrass) proved to be more important (Haegele and Miller, 1979).

The egg density on eelgrass declined from approximately 2,000 eggs/g eelgrass to about 300 eggs/g eelgrass during the incubation period. In the Miramichi study by Pottle et al. (1980) the highest egg density for an algal species was for Phyllophora sp. at 22 eggs/g. Even taking the major species for egg deposition the egg density was only 38 eggs/g algae for 5 algal species (98% by weight of algae).

The decline in egg density in the present study represents an 85% loss of eggs or mortality during the 19 day incubation period (4.5% a day). Actually the mortality appears to have occurred primarily in the initial 5 day period and this gives an egg mortality of 17%/day during this period. The decline in egg density was possibly a result of egg predation. Though not directly

studied in Ross Cove, observations from a North Cove spawning in 1980 indicated a considerable influx of winter flounder (Pseudopleuronectes americanus) onto the spawning bed. Stomach samples from a number of fish generally indicated considerable feeding activity on herring eggs. Some cod were taken as well with stomachs full of eggs. Also, there was the possibility of gull predation in Ross Cove, since the spawning bed was in shallow water and gulls were often noted in the vicinity. Tibbo et al. (1963) also found a large number of winter flounder feeding on herring eggs ($\sim 1/m^2$) and estimated a total egg mortality of 7% due to flounder, which is considerably lower than estimated in the present study. On a Georges Bank spawning bed Caddy and Iles (1973) estimated a predation mortality of 8% within 1-2 days after spawning which could amount to 60-70% total mortality for an 8-9 day incubation period (10C). In Miramichi Bay, Pottle et al. (1980) also noted a heavy concentration of winter flounder, even in the latter part of the incubation period. For a spawning study on Jeffrey Ledge, Gulf of Maine, the cunner (Tautogolabrus adsperous) was the most abundant predator and 70% of the cod showed evidence of feeding on eggs (Cooper et al. 1975).

Additional egg mortality was noted during the period of incubation with dead (opaque) eggs representing 6.4 - 8.5% of the egg samples. This was perhaps environmentally induced either through lack of fertilization or embryonic development. Marked fluctuations in temperature and salinity were measured during the incubation phase. Holliday

and Blaxter (1969) found that fertilization was only 70% complete at a salinity of 5.9°/oo, 80% complete at 11.5°/oo, and 100% complete at 22.7°/oo. Hatching success was also influenced by salinity with only a 5% hatch at 5.9°/oo, 60% hatch at 11.5°/oo and 86% hatch at 22.7°/oo. The lowest salinity recorded during the incubation period in Ross Cove was 1.8°/oo.

This type of egg mortality (environmental) in Ross Cove was higher than observed at other spawning locations in the Northwest Atlantic. Cooper et al. (1975) estimated that only 1% of the eggs sampled on Jeffreys Ledge were dead and the same low mortality was observed on a Georges Bank spawning ground (Pankratov and Sigajev, 1973). Comparable results have been found in the spring spawner studies of the Gulf of St. Lawrence. Tibbo et al. (1963) indicated that dead eggs were neglibible in samples from Chaleur Bay and a 1.8% egg mortality was noted for egg samples from Miramichi Bay (Pottle et al., 1980). A characteristic of these spawning locations is a relatively stable temperature and salinity regime, particularly in the deeper waters of the fall spawning sites.

European studies have also generally found a relatively low egg mortality during the incubation period. Parrish et al. (1959) reported only a 1% egg mortality for spawning of Clyde herring and Baxter (1971) recorded egg mortalities of 3.9-5.7% for the same stock. Bowers (1969) found only 1.4% dead or unfertilized eggs on the

spawning bed of Manx herring. Estimates of egg mortality in North Sea herring, based on stomach analysis of haddock, averaged about 4.2% (Hempel and Hempel 1971). However, for thick egg masses Runnstrom (1941) found an average mortality of 12% off the Norwegian Coast.

Higher egg mortalities have been reported for the Pacific herring (Clupea pallasii) for eggs deposited in the littoral zone (Taylor, 1971; Jones, 1972) but Haegele et al. (1979) found only a 2% egg mortality in 1258 spawn samples taken primarily from sublittoral spawning beds. They further estimate that egg loss due to air exposure, bird predation and storm damage probably does not exceed 10%, though no mention was made of fish predation.

The combination of predation and environmental induced egg mortality in the present study is significant and would appear to be higher than in most other studies. There is a definite need to assess these mortality factors in more detail since they have generally not been included in the determination of year-class success.

Larval density dramatically increased over the Ross Cove spawning bed during the 5 day hatching period. The degree of concentration would seem to be a result of the shallow depth. Graham and Chenoweth (1973) reported a mean larval density of 43 larvae/m^3 for plankton tows (30, 20 m and surface) near a spawning bed on Georges Bank. The

marked decline in larval concentration over the spawning bed in Ross Cove was presumably a result of dispersal and mortality but further work is required to quantify these parameters. Much emphasis has been placed on the "critical period" concept originally put forth by Hjort (1914). Various studies have attempted to provide evidence for this concept but with conflicting evidence for a "critical period" at yolk sac absorption (May, 1974). If the concept is broadened out to include later stages of development, then there appears to be more evidence to support the theory.

Estimates of larval mortality vary considerably but bear some relationship to the size or age of the larvae. Dragesund and Nakken (1971) found a 94% mortality in Norwegian spring herring larvae at the time of yolk sac absorption (27% per day). For Georges Bank herring larvae Graham and Chenoweth (1973) estimated 7.5% mortality (25% per day) for larvae less than 10 mm over a 4 day period. Off western Maine Graham and Davis (1971) found that winter mortality of larval herring varied from 22-52% for a 15 day period (Dec.-Jan.). This is comparable to a mortality rate of 3-5% per day found in Georges Bank Nantucket Shoal larvae from December - February (Lough et al. 1979). In perhaps the most complete study to date Graham (1980) found that winter larval mortality ranged from 32-96% (3 months) for the years 1964-1977. Graham considers that the larval year-class strength for autumn spawners is

determined by a density dependent phase of mortality in autumn and a density independent phase of mortality during winter, which may be modified by late spawning and relocation of spawning sites.

Estimates of growth rate for recently hatched larvae from Ross Cove (0.24 mm/day) are comparable to other studies. For autumn spawning stocks in the Georges Bank - Gulf of Maine area estimates of larval growth were 0.17 mm/day (0.14-0.25 mm/day) from September - June (Boyar et al. 1973). Lough et al. (1979) reported an average growth rate of 0.20 mm/day over 163 days for larval herring from Georges Bank - Nantucket Shoals area. The most complete study for larval growth in the Georges Bank - Gulf of Maine area utilized the Gompertz growth curve and otolith analysis to give an average rate of 0.195 mm/day over 150 days, with growth increasing from 0.251 mm/day at hatch to 0.297 mm/day at 20 days and decreasing to <0.152 mm/day after 75 days (Lough et al. 1980). For the Bay of Fundy region Das (1968) estimated growth to be 0.29 mm/day in early September, 0.21 mm/day in October and November and 0.14 mm/day during winter.

The Gulf of St. Lawrence has both spring and fall spawning stocks. Messieh and Kohler (1972) estimated larval growth of 0.20 mm/day during May through June, 1968 and 0.27 mm/day for the same months in 1969 presumably for spring spawned fish. Ware and Hendriksen (1978) further assessed the growth rate of larvae from the southern Gulf and postulate four groups of larvae which hatch at different

times and have different growth rates. The growth rates of the spring spawning groups A and B were 0.46 and 0.16 mm/day, respectively, whereas the growth rates of the late summer - fall spawning groups were 0.15 and 0.12 mm/day, respectively. Spawning group A refers to the Magdalen Islands and indicates a very high growth rate. The Bras d'Or Lake larval growth rate was approximately 50% less than for the Magdalens but higher than the other spawning groups. However, growth estimates in the present study were for a short period and presumably growth rate would decline with time, based on the study of Lough et al. (1980).

Stock Analysis

The intensity of spawning in West Bay may have declined markedly from 1980 to 1981, based on several observations. First, there appeared to be a sharp reduction in egg deposition in North Cove from 1980 to 1981. Second, plankton tows at various locations in West Bay in 1981 gave little indication of spawning other than in Ross Cove and North Cove. Whereas, in 1980 larval herring were present in Clarke Cove, Little Harbour and North Cove (B. Beaton, pers. comm.). Third, the 1981 commercial catch of herring in the Bras d'Or Lake declined considerably from the 1980 catch level. There is the possibility that spawning occurred in some offshore shoal areas but the plankton tows should have detected this.

A fundamental problem in assessing the Bras d'Or Lake stock concerns the migratory habits of these fish. Some fishermen express the view that little or no movement out of the Lake occurs, whereas others consider that the spawning fish move in from the Sydney Bight. Tagging studies by Fisheries and Oceans in 4Vn are beginning to shed some light on the stock relationships for this region (Sinclair et al. 1980). In 1979-1980 tagging was done primarily in the Bird Islands to Ingonish Bay area. A number of tags were recovered from 4Vn and also 3 tags were recovered from within the Bras d'Or Lake at Whycogomagh Bay and Militia Point (J. Simon and C. Dickson, pers. comm.). From a 1981 tagging operation near Englishtown, St. Anne's Bay a tag was recovered at Pipers Cove only 3 days after the tagging day. Tagging within Bras d'Or Lake has been limited with 600 fish tagged in North Cove, West Bay in 1980 (N.S. Dept. Fisheries) but to date there have been no returns from this operation.

Based on the tag return data it appears that stocks from the Atlantic Coast and Gulf of St. Lawrence overwinter in 4Vn. The tagging information also indicates that the Bras d'Or Lake herring may overwinter in the Sydney Bight - Ingonish region. However, the degree of migration is unknown and there appears to be no present means of quantifying the spring movement into the Bras d'Or Lake or using standard biological methods for stock assessment.

Acknowledgements

Our sincere thanks to the commercial fishermen in the Bras d'Or Lake region who provided fish samples and information about the fishery. In particular we would like to thank J. Kehoe for his assistance in our study. We greatly appreciate the use of laboratory space provided by Fisheries and Oceans in Halifax and Sydney, with a special thanks to R. Britten, A. MacKinnon and M. Gilligan. We are grateful to N. Pepper and C. Cooper for typing the report.

References

Anthony, V.C. and G.T. Waring. 1980. Estimates of herring spawning stock biomass and egg production for the Georges Bank - Gulf of Maine region. NAFO SCR Doc. 80/IX/135, 38p.

Baxter, I.G. 1971. Development rates and mortalities in clyde herring eggs. Rapp. P.V. Reun. Cons. Perm. Int. Explor. Mer. 160:27-29.

Beverley-Burton, M., O.L. Nyman and I.H.C. Pippy. 1977. The morphology, and some observations on the population genetics of Aniskasis simplex larvae (Nematoda: Ascaridata) from fishes of the North Atlantic. J. Fish. Res. Bd. Can. 34:105-112.

Blaxter, J.H.S. 1957. Herring rearing. III. The effect of temperature and other factors on myotome counts. Mar. Res. Scot. 1:16p.

Bowers, A.B. 1969. Spawning beds of Manx autumn herrings. J. Fish. Biol. 1:355-359.

Boyar, H.C., R.R. Marak, F.E. Perkins, and R.A. Clifford. 1973. Seasonal distribution and growth of larval herring (Clupea harengus L.) in the Georges Bank - Gulf of Maine area from 1962 to 1970. J. Cons. Int. Explor. Mer. 35:36-51.

Caddy, I.F. and T.D. Iles. 1973. Underwater observations on herring spawning grounds. Int. Comm. Northw. Atl. Fish. Res. Bull. 10:131-139.

Cooper, R.A., J.R. Uzmann, R.A. Clifford and K.I. Pecci. 1975. ICNAF Res. Doc. 75/93:6p.

Crawford, R.H. 1979. A biological survey of the Nova Scotia herring fishery, 1978. Nova Scotia Dept. Tech. Rep. 79-05:41p.

Crawford, R.H. 1980. A biological analysis of herring from the Atlantic coast of Nova Scotia and eastern Northumberland Strait. Nova Scotia Dept. Fish. Tech. Rep. 80-03:45p.

Cote, G. and H. Powles. 1978. The herring population of the St. Lawrence estuary. CAFSAC Res. Doc. 78/44:14p.

Das, N. 1968. Spawning distribution, survival, and growth of larval herring (Clupea harengus L.) in relation to hydrographic conditions in the Bay of Fundy. Fish. Res. Bd. Can. Tech. Rep. 88:129p.

Davey, I.T. 1971. A revision of the genus Aniskasis Dujardin, 1845 (Nematoda:Ascaridata). J. Helminth. 45:51-72.

Doyle, M.J. 1977. A morphological staging system for the larval development of the herring, Clupea harengus J. Mar. Biol. Ass (U.K.) 57:859-867.

Dragesund, O. and O. Nakken. 1971. Mortality of herring during the early larval stage in 1967. Rapp. P.V. Reun. Cons. Int. Explor. Mer. 160:142-146.

Graham, J.J. 1980. Production of larval herring, Clupea harengus, along Coastal Maine (1964-1978) and its relation to recruitment mechanisms of the sardine fishery. NAFO SCR Doc. 80/IX/123:30p.

Graham, J.J. and S.B. Chenoweth. 1973. Distribution and abundance of larval herring, Clupea harengus harengus, over egg beds on Georges Bank, Int. Comm. Northw. Atl. Fish. Res. Bull. 10:141-149.

Graham, J.J. and C.W. Davis. 1971. Estimates of mortality and year-class strength of larval herring in Western Maine, 1964-67. Rapp. P.V. Reun. Cons. Int. Explor. Mer. 160:147-152.

Haegele, C.V., A.S. Hourston, R.D. Humphreys, and D.C. Miller. 1979. Eggs per unit area in British Columbia herring spawn depositions. Fish. Mar. Serv. Tech. Rep. 894:30p.

Haegele, C.V., R.D. Humphreys, and A.S. Hourston. 1981. Distribution of eggs by depth and vegetation type in Pacific herring (Clupea harengus pallasi) spawnings in southern British Columbia. Can. J. Fish. Aquat. Sci. 38:381-386.

Haegele, C.W. and D.C. Miller. 1979. Assessment of 1979 herring spawnings in Chatham Sound, British Columbia. Fish. Mar. Ser. MS. Rep. 1437:37p.

Hart, J.L. and A.L. Tester. 1934. Quantitative Studies on herring spawning. Trans. Am. Fish. Soc. 64: 307-312.

Hempel, I. and G. Hempel. 1971. An estimate of mortality in eggs of North Sea herring (Clupea harengus L.). P.V. Reun. Cons. Perm. Int. Explor. Mer. 160:24-26.

Hempel, G. and J.H.S. Blaxter. 1961. The experimental modification of meristic characters in herring (Clupea harengus L.). J. Cons. Perm. Int. Explor. Mer. 26:336-346.

Hunt, J.J. and G.H. Winters. MS, 1979. Separation of spring and fall spawning groups. St. Andrews and St. John's Biological Stations, 7p.

ICNAF. 1964. Report of standing committee on research and statistics. App. 1. Report of ad hoc group on herring and other pelagic fish. Int. Comm. Northw. Atlantic Fish. Redbook. 1964, Part 1:23-30.

Hodder, V.M. 1972. The fecundity of herring in some parts of the Newfoundland area. Int. Comm. Northw. Atl. Fish. Res. Bull. 9:99-107.

Hodder, V.M. and L.S. Parsons. 1971a. Comparisons of certain biological characteristics of herring from Magdalen Islands and Southwestern Newfoundland. Int. Comm. Northw. Atl. Fish. Res. Bull. 8:59-65.

1971 b. Some biological features of southwest Newfoundland and northern Scotian Shelf herring stocks. Int. Comm. Northw. Atl. Fish. Res. Bull. 8:67-73.

Holliday, F.G.T. and J.H.S. Blaxter. 1960. The effects of salinity on the developing eggs and larvae of the herring. J. Mar. Biol. Ass (U.K.) 39:591-608.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapp. P.V. Reun. Cons. Int. Explor. Mer. 20:1-228.

Jones, B.C. 1972. Effect of intertidal exposure on survival and embryonic development of Pacific herring spawn. J. Fish. Res. Bd. Can. 29:1119-1124.

Kagei, N. 1968. Infection and prevention of Aniskasis. Kagaku-Asaki. 28:97-103.

Krauel, D.P. 1975. The physical oceanography of the Bras d'Or Lakes 1972-72. Fish. Mar. Serv. Dev. Tech. Rep. 570.

Lough, R.G., G.R. Bolz, M.D. Grosslein, and D.C. Potter. 1979. Abundance and survival of sea herring (Clupea harengus L.) larvae in relation to environmental factors, spawning stock size, and recruitment for the Georges Bank area, 1968-1977 seasons. ICNAF Res. Doc. 79/VI/112:47p.

Lough, R.G., M.R. Pennington, G.R. Bolz, and A.S. Rosenberg. 1980. A growth model for larval herring (Clupea harengus L.) in the Georges Bank - Gulf of Maine area based on otolith growth increments. NAFO SCR Doc. 80/IX/131:16p.

Margolis, L. and M.D. Dailey. 1972. Revised annotated list of parasites from sea mammals caught off the west coast of North America. Tech. Rep. Nat. Mar. Fish. Ser. U.S. SSRF-647:1-23.

McGurk, M.D., J.M. reen, W.D. McKone, and K. Spencer. 1980. Condition indices, energy density and water and lipid content of Atlantic herring (Clupea harengus harengus) of southeastern Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 958:41p.

McKenzie, R.A. 1964. Observations on herring spawning off southwest Nova Scotia J. Fish. Res. Bd. Can. 21(1):203-204.

Messieh, S.N. 1976. Fecundity studies on Atlantic herring from the southern Gulf of St. Lawrence and along the Nova Scotia coast. Trans. Am. Fish. Soc. 3:384-394.

Messieh, S.N. and A.C. Kohler. 1972. Distribution, relative abundance and growth of larval herring Clupea harengus L. in the southern Gulf of St. Lawrence. Fish. Res. Bd. Can. Tech. Rep. 318:30p.

Messieh, S.N. and J. Longmuir, 1978. The interrelationships between herring stocks in the Canadian Atlantic Fisheries as revealed by multivariate analyses of their meristic characteristics. CAFSAC Res. Doc. 78/45:9p.

Oshima, T., T. Shimazu, H. Koyama, and H. Okahane. 1969. On the larvae of the genus Aniskasis (Nematoda-Aniskinae) from the Euphausiids. Jap. J. Parasit. 18:241-8.

Pankratov, A.M. and I.K. Sigajev. 1973. Studies on Georges Bank herring spawning in 1970. Int. Comm. Northw. Atl. Fish. Res. Bull. 10:125-129.

Parrish, B.B., A. Saville, R.E. Craig, I.G. Baxter, and R. Priestley. 1959. Observations on herring spawning and larval distribution in the Firth of Clyde in 1958. J. Mar. Biol. Ass. U.K. 38:445-453.

Parsons, L.S. 1973. Meristic characteristics of Atlantic herring (Clupea harengus L.) stocks in Newfoundland and adjacent waters. Int. Comm. Northw. Atl. Fish. Res. Bull. 10:37-52.

Parsons, L.S. and V.M. Hodder. 1971. Variations in the incidence of larval nematodes in herring from Canadian Atlantic Waters. Int. Comm. Northw. Atl. Fish. Res. Bull. 8:5-14.

Parsons, L.S. and V.M. Hodder. 1975. Biological characteristics of southwest Newfoundland herring, 1965-1971. Int. Comm. Northw. Atl. Fish. Res. Bull. 11:145-160.

Perkins, F.E. and V.C. Anthony. 1969. A note on the fecundity of herring (Clupea harengus harengus L.) from Georges Bank, the Gulf of Maine and Nova Scotia. Int. Comm. Northw. Atl. Fish. Redbook 1969, Part III:33-38.

Pottle, R.A., P.A. MacPherson, S.M. Messieh and D.S. Moore. 1980. A scuba survey of a herring (Clupea harengus L.) spawning bed in Miramichi Bay, N.B. Can. Tech. Rep. Fish. Aquat. Sci. 984:7p.

Runnstrom, S. 1941. Quantitative investigations on herring spawning and its yearly fluctuations at the west of Norway. Fiskeridir. Ska. Havundersok. 6(8):1-71.

Schultz, H. 1974. The fecundity of Georges Bank herring in 1971. Int. Comm. Northw. Atl. Fish. Res. Doc. 74/119:8p.

Scott, J.S. 1975. Meristics of herring (Clupea harengus L.) from the Canadian Maritimes area. Fish. Mar. Serv. Tech. Rep. 599:24p.

Sinclair, M., W. Stobo and J. Simon. 1980. 1979-1980 4 Vn Herring Assessment. CAFSAC Res. Doc. 80/50.

Sinderman, C.J. 1961. Parasite tags for marine Fish. J. Wild. Mgmt. 25:41-47.

Smith, J.W. 1971. Thysanoessa inermis and I. longicaudata (Euphausiidae) as first intermediate hosts of Aniskasis sp. (Nematoda:Ascaridata) in the Northern Sea, to the north of Scotland and at Faroe. Nature Lond. 234:478.

Taning, A.V. 1952. Experimental study of meristic characters in Fishes. Biol. Rev. 27:169-193.

Taylor, F.H.C. 1971. Variations in hatching success in Pacific herring (Clupea pallasii) eggs with water depth, temperature, salinity, and egg mass thickness. Rapp. P.V. Reun. Cons. Perm. Int. Explor. Mer. 160:34-41.

Tibbo, S.N. 1957. Contribution to the biology of herring (Clupea harengus L.) on the Atlantic coast of Nova Scotia. Bull. Fish. Res. Bd. Can. 111:139-151.

Tibbo, S.N., D.J. Scarratt, and P.W.G. McMullon. 1963. An investigation of herring (Clupea harengus L.) spawning using free diving techniques. J. Fish. Res. Bd. Can. 20(4):1067-1079.

Ware, D.M. and B.L. Hendriksen. 1978. On the dynamics and structure of the southern Gulf of St. Lawrence herring stocks. Fish. Mar. Serv. Tech. Rep. 800:83p.

Williams, W.P. 1967. The growth and mortality of four species of fish in the River Thames at Reading. J. Anim. Ecol. 36:695-720.